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Doctoral thesis

Individual differences in syntactic  
knowledge and processing:  
Exploring the role of literacy experience

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**Individual differences in syntactic knowledge and processing:  
Exploring the role of literacy experience**

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*To BD, who showed me that language is more than words.*

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# 1. Introduction

When did you last see a young person engrossed in a book? The habit of reading for pleasure appears to be in decline, and nowhere more so than in the Netherlands, according to the Programme for International Student Assessment (PISA). In a survey of half a million 15-year-olds in 77 countries, participants in the Netherlands were the least likely to report taking pleasure in reading. Indeed, 40 percent considered it a waste of time (OECD, 2019). The unpopularity of reading is arguably both a symptom and a cause of a wider societal issue: the increasing incidence of low literacy. The same study found that one in four 15-year-olds reads below the minimum level necessary to function at school and in society, putting them at risk for low literacy in adulthood (Gubbels et al, 2019; OECD, 2019). Low literacy already affects more than 1.3 million adults of working age in the Netherlands, with significant personal, social, and economic costs (Algemene Rekenkamer, 2016). Acknowledging the urgent need for preventative action, the Dutch government recently launched a “reading offensive”: a systematic campaign to engage young people in book reading, for example through mentoring and investment in public libraries (Raad voor Cultuur & Onderwijsraad, 2019).

The PISA findings attest to the reciprocal relationship between reading for pleasure and literacy achievement: those who enjoy reading practise more frequently, improving their skills such that reading becomes more rewarding, which in turn motivates further practice, and so on. This so-called “virtuous cycle of reading” (Pfof et al., 2013) is observable from the earliest stage of literacy acquisition, when the first children to crack the letter-sound code quickly gain a much larger volume of reading experience than their more slowly progressing peers (Cunningham & Stanovich, 1998). The resulting achievement gap grows exponentially over time in a “spiral of causality”, implicating not only reading proficiency but also oral language skills. For example, increased print exposure

is reliably associated with vocabulary growth in children and, to an even greater extent, young adults (for a meta-analysis see Mol & Bus, 2011).

Compared to the large literature on vocabulary, the benefits of reading for other language abilities have not been as extensively researched, with even fewer studies addressing how differential written language input plays out in adulthood. A particular gap in our understanding concerns the contribution of life-long literacy experience to adult language users' knowledge and processing of syntactic structure. My thesis aims to shed light on this question in the Dutch context, from a variety theoretical and methodological perspectives. First, I will briefly explain what I mean by syntactic abilities and discuss the properties of written language that might enhance them.

To comprehend a spoken or written sentence, knowledge of individual word meanings is not enough. It is also important to understand the syntax – how words combine to create meaning. For example, *The student the teacher helped finished the book* is difficult to compute without analysing the embedded clause (*the teacher helped*) as a separate unit. Such processing strategies rely on syntactic knowledge that for adult native speakers is often implicit. However, even in the healthy adult population, syntactic abilities are subject to considerable individual differences (e.g., Dąbrowska, 2008; Dąbrowska, 2018; Farmer et al, 2012; Langlois & Arnold, 2020; Street & Dąbrowska, 2010).

Being able to decode (or parse) the syntax of a sentence may be especially critical when reading, because of the absence of other cues to support comprehension such as prosody and gesture, which are typically available in speech. The fact of focusing attention on linguistic form is one way in which reading could be expected to train syntactic abilities (Ravid & Tolchinsky, 2002); another way is through exposure to the specifics of the linguistic form itself.

### *'Book language'*

Different written registers (e.g., novels, newspapers, and academic texts) are characterised by different syntactic patterns, often related to their discourse function (e.g., narrative or expository; Biber, 1993). Nevertheless, in terms of variety and complexity, it is safe to say that written language in general offers a rich syntactic experience in comparison to conversational speech. I use the term

‘book language’ (Huettig & Pickering, 2019) in this thesis to refer to the set of linguistic properties (not exclusive to books) that differentiate written texts from informal spoken language. One such property is syntactic diversity. Corpus evidence from English indicates that relatively low-frequency structures such as object clefts, participial phrases, passive relative clauses, and passives in general, are disproportionally represented in written texts (Biber, 1991; Montag & MacDonald, 2015; Roland et al., 2007). Add to this list highly literary constructions that are vanishingly rare in conversational speech (e.g., *No sooner had I arrived...*), and it seems reasonable to assume that avid readers enjoy a varied syntactic diet.

A related property of ‘book language’ is syntactic complexity. The written modality lends itself to elaborate sentence structures, free from the processing limitations (e.g., working memory) that constrain spoken production (Sedivy, 2017). This is illustrated by the predominance of subordination in written narratives compared to spoken sentences (Kroll, 1977, cited by Kolinsky & Morais, 2018). Relatedly, written corpora are more likely to contain syntactic structures with high processing demands, such as relative clauses with an embedded full noun phrase (Scott, 2009). Taken together, evidence from comparative corpus studies thus suggests that ‘book language’ may be a uniquely rich source of stimulation for syntactic skills.

### *Literacy and syntactic abilities*

What is the evidence to date that literacy experience contributes to syntactic abilities? Several previous studies have linked differential written language input to individual differences in syntactic knowledge and processing. Montag and MacDonald (2015) investigated productive knowledge of passive relative clauses, based on their predominance in analysed written corpora relative to spoken corpora. They found that print exposure predicted the use of passive relative clauses during spoken picture description in both children and adults. These results suggest that long-term exposure to the syntactic environment of ‘book language’ can influence speakers’ implicit sentence production choices, consistent with the experience-based view that linguistic behaviour is modulated by the input a language user receives (Abbot-Smith & Tomasello, 2006; Bybee

2006; for further experimental evidence see Wells et al., 2009). Relatedly, Street and Dąbrowska (2010) found that auditory comprehension of full passive sentences correlated with self-reported volume of reading in adults with low educational attainment (no formal qualifications). By eliminating the potential confound of education, this study provides evidence for a specific effect of reading practice on receptive knowledge of the passive construction. Other syntactic abilities previously linked to literacy experience include ambiguous pronoun interpretation based on syntactic cues (Langlois & Arnold, 2020) and, to some extent, comprehension of basic constructions frequently used in spoken English (e.g., quantified noun phrases; Dąbrowska, 2018). Even in pre-literate children (aged 24 and 30 months), longitudinal evidence suggests that exposure to ‘book language’ through shared story reading contributes to syntactic development (Crain-Thoreson & Dale, 1992).

Thus, there is some evidence to support the hypothesis that individual differences in syntactic proficiency are at least partly related to differential written language input. However, the findings to date concern a relatively small set of structures from only one language (English), making it difficult to draw general conclusions about the extent to which life-long exposure to ‘book language’ enhances readers’ syntactic abilities. Another limitation affecting most previous adult studies is the reliance on a single measure of literacy experience (discussed below), which may lack the sensitivity to capture the full range of individual differences that is expected in the general population.

### *Measuring literacy experience*

“Literacy is not a skill, nor a capacity, but a complex attribute that depends on experience” (Morais, 2018). This thesis is concerned with the experiential dimension of literacy, on the basis that literate individuals vary considerably in the degree to which they engage in print-related activities (Stanovich & West, 1989). A widely used proxy for literacy experience (also called print exposure) is the Author Recognition Test (ART), first developed by Stanovich and West (1989). This checklist of literary and best-selling authors (appropriate to the population being studied) is argued to probe an individual’s literacy environment in an unobtrusive manner, with non-existing author names included to correct for

guessing. More frequent readers are expected to discriminate better between real and fake author names, due to greater familiarity with the world of print (West et al., 1993). The ART is also thought to be more objective than measures based on self-reported reading habits, which are prone to social desirability bias (i.e., respondents tend to over-estimate the amount of time spent reading; Zill & Winglee, 1990). Supporting its validity as a proxy for literacy experience, the ART has been shown to correlate well with literacy-related skills such as orthographic processing, spelling, vocabulary knowledge, and reading comprehension (Cunningham & Stanovich, 1998; Stanovich & Cunningham, 1992; Stanovich and West, 1989).

Although common practice in the literature, relying on the ART alone to measure literacy experience inevitably has limitations. Most importantly for the purposes of this thesis, the test is unlikely to capture sufficient variation amongst individuals at the lower end of the literacy experience distribution, who may have difficulty recognising any author names. Indeed, it appears that ART scores of zero or below are not uncommon, particularly in non-undergraduate populations (e.g., Dabrowska, 2018; Langlois & Arnold, 2020). Given the likelihood of floor effects in the lower range, I chose to avoid over-reliance on the ART. Instead, I used a battery of proxy measures of literacy experience that included the ART, in addition to tests of receptive vocabulary, word-reading, pseudo-word reading, spelling, and a reading habits questionnaire (described in full in Chapter 2). The rationale for this broad-based approach was to reflect the multifaceted nature of literacy, as emphasised by Morais (2018). Using a composite of multiple measures was also intended to mitigate the impact of any limitations associated with individual components (e.g., potential social desirability bias on the reading habits questionnaire).

### *Individual differences approach*

Kidd et al. (2018) argued that the traditional practice in psycholinguistic research of treating between-participant variability as experimental noise has created a misleading impression of invariance in the human language capacity. Contrary to this, a growing body of evidence demonstrates pervasive individual differences across the language system and throughout the lifespan. In the syntactic domain,



both online processing and ultimate attainment (i.e., knowledge) have been shown to vary considerably among healthy adults, as a function of both cognitive and environmental factors (Kidd et al., 2018). Indeed, recent evidence that adult native speakers do not all converge on the same internal grammar (reviewed by Dąbrowska & Divjak, 2019) has presented a challenge to influential theories in the formal linguistics tradition (e.g., Chomsky, 1965; Crain & Lillo-Martin, 1999, Lidz & Williams, 2009; Nowak et al., 2001).

Individual differences are an inherent focus of this thesis, as I try to untangle the relationship between individual patterns of life-long syntactic experience on the one hand, and on the other, measurable differences in the knowledge and processing of syntactic structure. Throughout, intrinsic cognitive variables (e.g., working memory) are taken into account as additional sources of individual variation in language.

### *Community-based sampling*

While it remains the norm for psycholinguistic studies to sample university undergraduates, the practice has been widely criticised (Henrich et al., 2010). The inherent lack of diversity in this approach is problematic, not least because of the skewed evidence base it creates. Undergraduate students are unrepresentative of the general adult population in terms of language and literacy skills, as studies with community-based samples have shown (e.g., Braze et al., 2007; Kukona, 2016; Kuperman & Van Dyke, 2011, Ng et al., 2018). It is particularly in the interest of individual difference research to capture the widest possible range of ability and experience, by sampling beyond the typical university participant pool (Kidd et al., 2018). By including language users from a range of educational backgrounds and occupations, community-based samples are likely to be more informative for describing the experiential factors that contribute to individual differences in language. Community-based sampling was therefore a key objective of the research presented in this thesis. I made a concerted effort to recruit as many participants as possible from outside the ‘university bubble’ and to improve accessibility, for example by testing in local community settings (libraries and classrooms) where appropriate, rather than in the lab. Finally, to make the most of the data collected, all main results in this thesis are interpreted

using a magnitude estimation approach, which is considered more informative than null-hypothesis significance testing (Cumming, 2014).

### *Thesis outline*

This thesis presents five empirical studies. There may be some repetition across the chapters, which were written for publication as individual articles.

Chapter 2 describes a large-scale correlational study that investigated how individual differences in written language experience relate to explicit and implicit syntactic processes in spoken language. I recruited a community-based sample of 161 adult native Dutch speakers, with the aim of capturing a broad spectrum of literacy ability and experience. Participants completed a battery of literacy-related measures, to which I applied principal components analysis and took the first principal component (explaining approximately 40% of the total variance) as an index of written language experience. The explicit measure of syntactic knowledge was an auditory grammaticality judgment task, targeting four prescriptive grammatical norm violations in spoken Dutch. Comprehension-to-production priming of the Dutch dative alternation (a well-established finding in the literature) provided an implicit measure of syntactic processing. I administered further individual difference measures to control for the contribution of general cognitive abilities to task performance.

In Chapter 3, I take a closer look at receptive syntactic knowledge in a subset of participants from Chapter 2: those who scored in the top and bottom quartiles on the index of written language experience (described above). Again, I used a grammaticality judgment task to assess syntactic knowledge, but this time expanded the scope to include a much broader range of structures. As well as evaluating literacy-related differences, I aimed to probe the distinction espoused by many theorists, between a ‘core’ grammar that virtually all native speakers acquire, and a ‘peripheral’ grammar that most do not. I first gathered intuitions from Dutch linguist informants regarding the ‘core’ or ‘peripheral’ status of a wide selection of grammatical structures in Dutch. Structures with the highest ‘core’ and ‘peripheral’ ratings were then presented to naïve participants in the grammaticality judgment task. In testing participants from opposite ends of the literacy experience distribution, I aimed to shed light on the breadth of syntactic

knowledge that might be shared by the majority of adult native Dutch speakers. I also reasoned that this sampling approach offered the greatest chance of detecting any literacy-related differences in receptive syntactic knowledge, which some previous studies have observed.

The study reported in Chapter 4 involved the same two groups of participants who completed the grammar test in Chapter 3. I will refer to these groups as low literacy experience (LLE) and high literacy experience (HLE). I used the visual world paradigm to examine literacy-related differences in the predictive processing of syntactic structure. Participants listened to passive sentences in Dutch, while looking at visual scenes in which only one of the four entities pictured was a plausible agent, given the sentence context. I measured anticipatory eye-movements to the agent before it occurred in the speech signal as an index of syntactic prediction. By comparing the prediction effect between groups while controlling for lexical processing speed and other individual differences, I aimed to determine the unique contribution of written language experience to anticipatory syntactic processing in spoken language. I hypothesised that the HLE group would be faster than the LLE group to look at the upcoming agent, reflecting more efficient parsing of the unfolding passive sentence.

In Chapter 5, the visual world paradigm is used to investigate an instance of syntactic prediction that relies exclusively on fine-grained information contained within individual verbs. My approach was closely based on previous work by Arai and Keller (2013, Experiment 1), in which verb transitivity was manipulated as a cue to predict upcoming direct objects in English. Arai and Keller observed an increase in anticipatory eye movements to the plausible direct object entity in a scene when the spoken sentence contained a transitive verb, relative to an intransitive control condition. The aim of Chapter 5 was to investigate the presence of such an effect in Dutch, where transitive verbs impose the same constraints on post-verbal arguments as in English. If observed, I was also interested in examining individual differences in syntactic prediction with respect to literacy experience. To this end, the experiment was conducted with the HLE and LLE groups described above, as part of a longer testing session that also included the experiments reported in Chapters 3 and 4.

Finally, in Chapter 6, I return to syntactic priming, this time from a cross-linguistic perspective. In contrast to the specific focus on literacy experience in the previous chapters, Chapter 6 takes a broader view of language experience, asking how long-term exposure to two languages affects online syntactic processing. I investigated syntactic priming of datives and passives from Irish Gaelic to English in bilingual adolescents. This was motivated by a call for syntactic priming research in less studied languages and gave me the opportunity to conduct field work in secondary schools across Ireland.



## **2. Long-term written language experience affects syntactic awareness and usage but not syntactic priming of spoken sentences<sup>1</sup>**

‘Book language’ offers a richer linguistic experience than typical conversational speech in terms of syntactic complexity. Here, we investigated the contribution of long-term syntactic experience to explicit syntactic knowledge and implicit syntactic processing. In a pre-registered study involving 161 adult native Dutch speakers with varying levels of literacy, we assessed the contribution of individual differences in written language experience to offline and online syntactic processes. Offline syntactic knowledge was assessed as accuracy in an auditory grammaticality judgment task in which we tested violations of four Dutch grammatical norms. Online syntactic processing was indexed by syntactic priming of the Dutch dative alternation, using a comprehension-to-production priming paradigm with auditory presentation. Controlling for the contribution of general cognitive abilities, we observed a robust effect of literacy experience on the detection of grammatical norm violations in spoken sentences, suggesting that exposure to the syntactic complexity and diversity of written language has specific benefits for general (modality-independent) syntactic knowledge. We replicated previous research by demonstrating robust comprehension-to-production syntactic priming, both with and without lexical overlap between prime and target. Although literacy experience affected the usage of alternating syntactic constructions in our large sample, it did not modulate their priming. We conclude that amount of experience with written language increases explicit awareness of grammatical norm violations and changes the usage of (prepositional-object vs. double-object) dative spoken sentences but has no detectable effect on their implicit syntactic priming in proficient language users.

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<sup>1</sup> Adapted from Favier, S. & Huettig, F. (under review) *Long-term written language experience affects syntactic awareness and usage but not syntactic priming of spoken sentences.*

## Introduction

Syntactic diversity and complexity are key characteristics of ‘book language’. Elaborate sentence structure is characteristic of written narratives, with subordination, for instance, found to be 60% more frequent than in spoken sentences (Kroll, 1977; cited by Kolinsky & Morais, 2018). Analyses of spoken and written corpora reveal pronounced asymmetry in the distributions of syntactic structures such as passives, object relative clauses, and participial phrases (e.g., Roland, Dick & Elman, 2007). It is important to note that exposure to the richer syntactic environment of ‘book language’ can similarly be gained from listening to audiobooks, or through shared reading for children. The associated benefits for syntactic knowledge can thus be considered a secondary influence of literacy, distinct from primary influences of literacy, which arise as a direct consequence of the physical act of reading (see Huettig & Pickering, 2019, for further discussion). For example, Crain-Thoreson and Dale (1992) observed a secondary influence of ‘literate activity’ in pre-literate children. Their longitudinal study showed that the frequency of shared story reading with parents at 24 months reliably predicted performance on an auditory standardised test of syntactic comprehension at 30 months.

The effects of written language experience on syntactic comprehension more generally have been the focus of recent research. Dąbrowska (2012) reviewed experimental work investigating the syntactic abilities of adult L1 speakers with varying levels of education and reported converging evidence for considerable individual differences in knowledge of ‘core’ syntactic structures (including complementation, quantifiers, and passives). Differences were robustly correlated with education: while high educational attainment groups tended to score at or near ceiling, performance among individuals with low educational attainment was often at chance. Regarding the underlying factor driving these effects, it was acknowledged that education could be acting as a proxy for print exposure. The two factors are of course intertwined (print exposure correlates with years of formal schooling, e.g., Dąbrowska, 2018), but there is some evidence for an independent contribution of print exposure to syntactic proficiency.

Street and Dąbrowska (2010) found that print exposure reliably predicted comprehension of passives in a group of adults matched for educational attainment. Reading experience was a weaker predictor of performance on quantifier constructions in the same study, possibly reflecting the more symmetrical distribution of quantified noun phrases across spoken and written modalities (in contrast to full passives which occur seven times more frequently in written texts). In later work testing comprehension of a range of grammatical constructions frequently heard in everyday conversation, Dąbrowska (2018) observed a significant (albeit small) unique contribution of print exposure.

Comprehension is not the only domain in which written language experience can have consequences for syntactic processing. Montag and MacDonald (2015) examined the effect of prior reading experience on implicit sentence production choices in children and adults. Individuals who scored highly on the Author Recognition Test (used as an index of print exposure) showed a pattern of production in their spoken language that reflected structural distributions in analysed written language corpora (specifically, increased frequency of passive relative clauses, which are rarely encountered in spoken language). This result leads straightforwardly to the conclusion that long-term exposure to a syntactic structure via reading facilitates its production in speech. The authors posited that becoming a reader entails a quantitative and qualitative shift in linguistic experience, which continues to shape syntactic behaviour throughout adulthood.

The current study investigated the contribution of individual differences in literacy experience to offline and online syntactic processes. This is an important question because experience-based theories of cognitive processing predict that experience/usage affects both explicit knowledge about a domain as well as implicit processing. In the domain of language, for example, it has been proposed that acquisition is shaped by the quality and quantity of the input (e.g., Abbot-Smith & Tomasello, 2006; Bybee 2006). ‘Book language’ is a source of high-quality input, based on its increased syntactic complexity and diversity relative to conversational speech (Kroll, 1977; Roland et al., 2007). In terms of input quantity, skilled readers encounter a larger volume of language through reading more, in addition to processing information at a faster rate than is possible for



listeners (e.g., skilled readers read English fiction at about 260 words per minute – approximately twice the typical speech rate; Brysbaert, 2019).

We chose to look at the effect of literacy experience on explicit syntactic knowledge (as indexed by grammaticality judgments) and implicit syntactic processing (as indexed by syntactic priming) because it is conceivable that experience influences explicit processes differently than implicit ones. It is important to point out that no psycholinguistic task involves purely explicit or purely implicit processes but a mixture of both. It is, however, generally agreed that grammaticality judgment and syntactic priming are located at opposite poles of this continuum. In the present study, we integrated correlational and experimental methods, using a correlational design with literacy experience as a predictor and grammaticality judgment accuracy and syntactic priming magnitude as the predicted variables.

### *Grammaticality judgment*

The grammaticality judgment task is an offline task and metalinguistic in nature. Though there is little doubt that it has implicit components, it calls strongly for explicit attention to the syntactic form of an utterance. In explaining the contribution of literacy to such a task, some have argued that the decontextualised nature of written language facilitates metalinguistic thinking (e.g., Ravid & Tolchinsky, 2002, see Huettig & Mishra, 2014, for a review). Dąbrowska (2018) posits that inferring meaning from written text requires greater focus on the linguistic form, because of the absence of extra-linguistic cues typically available in speech (e.g., prosody and gesture). As well as being more conducive to learning syntactic structures, this attention to form may also support the ‘meta-syntactic’ processes involved in grammaticality judgment. The idea that literacy brings with it an explicit analytical awareness of language itself is supported by evidence for the causal role of alphabetic literacy acquisition in meta-phonological abilities (e.g., phoneme deletion, Morais et al., 1979). For Kolinsky and Morais (2018), metalinguistic thinking is a key feature of the metaphorical “literate glasses” through which literate people perceive the world.

Dutch is an interesting case study for grammaticality judgment because of the prevalence of syntactic forms that are prohibited by prescriptive grammar but

nevertheless occur frequently in the daily speech of native Dutch speakers. Well-documented examples include the use of the object pronoun *hun* ‘them’ as a subject, and the comparative marker *als* ‘as’ in comparative constructions of inequality, where *dan* ‘than’ is prescribed. Spoken corpus analyses reveal the prevalence of these prescriptive norm violations to be highest among low educated speakers (Hubers & de Hoop, 2013; van Bergen et al., 2011).

### *Syntactic priming*

Syntactic (or structural) priming offers a tool to investigate how the language processing system represents implicit syntactic knowledge. Syntactic priming has more implicit components than metalinguistic tasks such as grammaticality judgment, though may involve some explicit components as well (e.g., Bernolet et al., 2016). Bock (1986) found that after hearing and repeating a sentence like *The corrupt inspector offered a deal to the bar owner*, participants were more likely to use a prepositional-object (PO) dative to describe an unrelated pictured event (e.g., *The girl is handing a valentine to the boy*), compared with its alternative, the double-object (DO) dative (*The girl is handing the boy a valentine*). Since it was first reported over thirty years ago, the effect of recent syntactic experience on subsequent production has been demonstrated with a variety of tasks, syntactic structures, and languages (see Mahowald et al., 2016, for a meta-analysis).

Evidence for syntactic priming in pre-literate children (e.g., Branigan & McLean, 2016) indicates that reading experience is not a pre-requisite. Nevertheless, syntactic priming is particularly interesting from the point of view of experiential influences because it has been described both as a short-term (e.g., Pickering & Branigan, 1998) and a long-term phenomenon (e.g., Chang 2002; Chang et al., 2000, 2006). Pickering and Branigan’s (1998) account of syntactic priming posits that verb lemmas and their associated combinatorial nodes (specifying structure) become activated during comprehension, and that residual activation in a given combinatorial node increases the likelihood of reproducing a recently encountered structure (Pickering & Branigan, 1998). Due to the rapid decay of residual activation, syntactic priming according to this account is a relatively short-term phenomenon. In contrast, Chang and colleagues (Chang

2002; Chang et al., 2000, 2006) propose that during comprehension, the system continuously updates the weighting of mappings between message-level and abstract syntactic representations according to the input it receives. This implicit learning model of syntactic priming thus predicts longer-term effects of experience on syntactic priming. In line with such an account, it has been observed that syntactic priming can persist over multiple intervening sentences (Bock & Griffin, 2000; Bock et al., 2007) and even a week (Branigan & Messenger, 2016). To reconcile long-term persistence with the short-lived boost to syntactic priming that occurs when prime and target sentences share a lexical head (e.g., Hartsuiker et al., 2008), it has been proposed that repeated lexical material may simply cue retrieval of the prime sentence in short term memory (Bernolet et al., 2016).

Long-term persistence of syntactic priming in the literature thus refers to priming over multiple intervening sentences or at maximum a week. To our knowledge, the question of whether *life-long* experience with alternating structures influences syntactic priming has not been directly explored. Life-long written language experience, for instance, may influence the usage of alternating structures because some alternates may be more prevalent in print materials. In the present study, we measure such a potential bias of written language experience directly by using a baseline measure of alternating Dutch dative (PO or DO) constructions in people with varying literacy levels (rather than relying on the small corpora that are available for Dutch, which may be prone to biases). If literacy experience changes the usage of alternating Dutch datives, then it is conceivable that this changes their syntactic priming. In activation-based accounts of information processing, for instance, infrequent structures get more of a boost than frequent structures from the same amount of activation, resulting in stronger priming. This is because more activation is required to raise the resting activation of a frequent structure (perhaps reaching ceiling asymptotically). In short, less written language experience may make certain structures more infrequent in individuals with lower literacy, potentially resulting in stronger priming for these structures.

### *The current study*

The current study investigated the contribution of individual differences in literacy experience to offline and online syntactic processes, as indexed by grammaticality judgment and syntactic priming respectively. Whilst the majority of participants in psycholinguistic research to date have been university students, this group is unrepresentative of the general population in terms of language and literacy skills, which are likely to be skewed towards the upper end of the distribution. Given the theoretical importance of sampling from a broad spectrum of literacy abilities (Tarone & Bigelow, 2005), we focused our efforts on recruiting participants from diverse educational backgrounds. In addition, we tested participants outside of the lab to facilitate community participation.

We measured a range of literacy-related skills as predictors: word and pseudo-word reading, receptive vocabulary knowledge, misspelling detection, author name recognition, and self-reported reading habits. We performed principal components analysis on these six variables to derive a principal component score, providing an index of literacy for our correlational analyses. To control for the effects of general cognitive abilities on our outcome measures, we also included tests of working memory capacity, processing speed and non-verbal intelligence in our battery. These served as covariates in the analyses.

We developed an auditory grammaticality judgment task to probe participants' knowledge of four prescriptive grammatical norms in Dutch; specifically, their sensitivity to norm violations that occur in the everyday speech of many native speakers (Hubers et al., 2016). Whereas previous studies have investigated the grammaticality of these predominantly spoken constructions via the written modality, we used auditory presentation in order to address the effect of written language experience on spoken language processing specifically. The task required participants to make a binary normative judgment about the syntactic form of each utterance (correct/incorrect). The within-subjects manipulated variable was grammaticality: whether or not the stimulus sentence violated a Dutch grammatical norm. Our outcome measure was the proportion of experimental items correctly judged as grammatical or ungrammatical, according to prescriptive usage. We predicted that native speakers' grammaticality judgments are influenced by their awareness of the syntactic discrepancies

between written and spoken Dutch. We assumed that this awareness correlates with reading experience (i.e., exposure to written language) as indexed by our literacy measures. Put another way, prescriptive grammatical norms are reliably attested in written language, whereas everyday spoken Dutch frequently contains violations of prescribed usage. Therefore, on the basis of differing input, we predicted that participants with less reading experience would have more difficulty recognising prescriptive norm violations (i.e., their judgments would be more likely to reflect the syntactic patterns of spoken language).

The syntactic priming experiment focused on the Dutch dative alternation, using a comprehension-to-production paradigm (following Bernolet & Hartsuiker, 2010). Participants alternated between listening to (prime) sentences, performing a picture verification task, and providing spoken responses to target pictures. Rather than generating dative sentences from written verbs as in some previous studies, participants in the current study completed dative sentence stems that were presented auditorily. This more constrained elicitation format was intended to minimise the impact of literacy-related abilities on task performance. Primes and their corresponding target pictures were adjacent, as immediate priming effects are expected to be stronger than priming after a lag (Bernolet et al., 2016). We manipulated the structure of the prime (prepositional-object or double-object dative, within items), and the repetition of the head verb between prime and target (verb same or different; within subjects). In line with previous research, we predicted that primed structures would be produced more frequently in the priming conditions. Furthermore, we predicted an increased likelihood of producing the primed structure when the prime verb was repeated in the target sentence (lexical boost). By including a baseline measure (rather than relying on limited evidence from Dutch corpora, Haemers, 2012; Coleman, 2009), we directly measured whether written language experience affects usage (base levels) of alternating Dutch dative (PO/DO) constructions, and in turn their syntactic priming. Finally, we also explored whether those with less literacy experience are more prone to the influence of repeated lexical material that cues retrieval of the prime sentence in short term memory (i.e., a greater lexical boost).

### *Pre-registered predictions<sup>2</sup>*

1. Literacy will be positively correlated with accuracy in an auditory grammaticality judgment task (directional).
2. Vocabulary knowledge will correlate positively with grammaticality judgment accuracy (directional).
3. Participants will produce more target completions containing the primed structure after hearing a prime sentence versus a structurally unrelated control sentence (directional).
4. The likelihood of producing the primed structure will be enhanced when the prime verb is repeated in the target sentence (lexical boost) (directional).
5. We predict a negative correlation between literacy and the magnitude of the syntactic priming effect observed (directional).
6. The lexical boost will be stronger in participants with lower literacy (directional).

## **Method**

The study was pre-registered with the Open Science Framework, including a sample size appropriate to its correlational, individual difference design. The sampling rationale was based on work by Schönbrodt and Perugini (2013), in which Monte-Carlo simulations of correlational analyses identified  $N=161$  as a point of stability for estimated correlation magnitudes, after which sample estimates do not deviate from a pre-defined ‘corridor of stability’ around the true population value.

### *Participants*

161 Dutch native speakers participated for €10 per hour. We recruited a community sample through online and local advertising in Nijmegen, the Netherlands. 20 participants were recruited and tested in their local public library. Email invitations were also sent to eligible native Dutch speakers aged 18 to 35

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<sup>2</sup> Pre-registered predictions can be viewed online at <https://osf.io/zykp2>

in the Max Planck Institute's participant database. None of the participants had a diagnosed reading disability and all had normal or corrected-to-normal hearing and vision. 13 participants were excluded from the analysis: 11 scored less than 2.5 standard deviations below the sample mean on at least one of the individual difference measures, and two had missing data.

### *Materials*

#### **1. Individual difference measures**

##### **Literacy-related abilities**

We developed a battery to assess a range of literacy-related abilities, both directly and indirectly. The battery comprised standardised assessments that have been widely used in the psycholinguistics literature, and some measures developed for the current study. Each is briefly described below.

##### Een Minuut Test

We administered a standardised test of word reading ability, consisting of 116 Dutch words that progressively increase in difficulty (Brus & Voeten, 1973). We instructed participants to read the list aloud from top to bottom as quickly as possible. The score was the number of words read accurately within one minute, precisely as printed on the test sheet. The experimenter timed the test using a stopwatch and scored responses on-line.

##### Klepel Test

We used a standardised test of pseudo-word reading ability, comprising 116 Dutch pseudo-words of progressively increasing complexity (Van den Bos et al., 1994). The administration and scoring procedure were as above, except that participants had two minutes to read aloud as many items as they could, as accurately as possible. Since some participants completed the list in less than two minutes, we also kept a record of their score after one minute. Digital voice recordings of both reading tests were made, and a native speaker later verified the scores.

### Peabody Picture Vocabulary Test

A large body of research highlights the bi-directional relationship between vocabulary knowledge and reading (e.g., Braze et al., 2007; Lee, 2011; Tannenbaum et al., 2006). In adulthood, most new words are encountered in written texts (Cunningham & Stanovich, 1998; Stanovich et al., 1995), making receptive vocabulary knowledge a useful proxy for literacy experience (not only oral language competence). We used a computerised version of the Dutch Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997; Dutch translation by Schlichting, 2005). Each trial comprised a spoken word and a visual display with four numbered line drawings. Participants selected the picture that illustrated the word's meaning by pressing the corresponding number on the keyboard. The task was self-paced and participants could listen to each word more than once. Trials were presented blocks of twelve, which progressively increased in difficulty. If the number of incorrect responses in a block exceeded seven, the test was discontinued. The raw score was the final item number reached, minus the total number of errors. From this the participant's standardised score and percentile rank were derived, based on Dutch age norms.

### Misspelling Detection Test

We developed a short paper test to assess receptive spelling knowledge, based on norms from Dutch and Flemish university students (Marc Brysbaert, personal correspondence). We selected a subset of 20 high-prevalence words with item scores that correlated the most with total test scores (0.30 – 0.55 correlation). We chose words from the higher end of the item score distribution (0.87 – 0.99 correct) to account for the wider range of ability in our community sample relative to the norming sample. Each correctly spelled word had a misspelled counterpart featuring a single substitution error, e.g., \*onbeminde (correct spelling: onbeminde). Two counterbalanced, pseudo-randomised lists were constructed such that all 20 words appeared in their correct and incorrect versions across the two lists and no more than three of the same condition appeared consecutively. Each word was presented in a plausible sentence context, e.g., Hij stierf onbeminde. We instructed participants to indicate whether the underlined



word in the sentence was correctly spelled or not by marking a tick or a cross on the test sheet.

### Author Recognition Test

The Author Recognition Test (ART; Stanovich & West, 1989) is widely used as a proxy for engagement in print-related activities. Adapted for the Netherlands and Belgium (Brysbaert et al., 2013), the test comprises 60 author names, known to 66% of the Dutch norming sample, and 30 non-author foils that yielded 13% false alarms. We instructed participants to indicate which authors they knew and advised them against guessing as false alarms would be penalised. The test was completed on paper and untimed. The score was the number of authors correctly identified, minus the number of foils marked.

### Reading Habits Questionnaire

A paper questionnaire was used to evaluate self-reported engagement in print-related activities. This was a Dutch translation of the subtest “Your Reading Activities”, extracted from the OECD Programme for International Student Assessment (PISA; OECD, 2009). Importantly, the questionnaire also probed time spent reading digital and online media. Participants answered questions on a four or five-point likert scale and the score was the sum of coded responses.

### **General cognitive abilities**

As literacy is known to correlate with general cognitive characteristics, we also administered a battery of control measures to assess non-verbal intelligence, processing speed, and verbal working memory.

### Raven’s Progressive Matrices

To assess participants’ non-verbal intelligence, we administered a shortened, computerised version of Raven’s advanced progressive matrices test (RPM; Raven, Raven & Court, 1993). The task was to indicate via mouse-click which of eight shapes completed a matrix of geometric patterns. Participants had 20 minutes to complete 36 items. It was possible to skip any item and return to it at the end of the test. The score was the total number of correct responses.

### Letter Comparison

As an index of processing speed, we used the letter comparison task (based on Salthouse & Babcock, 1991). Participants were presented with pairs of capital letter strings containing only consonants, in large black font on a white screen. The task was to indicate whether the strings were the same or different by pressing '1' or '0' respectively on the keyboard. Half of the items consisted of three-letter strings and the other half six-letter strings. Incongruent pairs differed by only one letter. There were six practice trials and 48 test trials, each beginning with a fixation cross, followed by a pair of letter strings that remained on the screen until the participant responded. There was an inter-trial interval of 1000ms. The score was calculated as the mean response time (RT) for all correct responses that were no more than three standard deviations slower than the participant's grand mean RT.

### Backward Digit Span

We used a computerised version of the backwards-recall digit span task to measure working memory capacity, with auditory presentation of stimuli (adapted from the Wechsler Adult Intelligence Scale, 1997). Participants listened via headphones to sequences of two to eight digits, spoken by a female Dutch native speaker with a consistent rate (1 second pauses) and neutral prosody. The task was to type the sequence heard in reverse order using the keyboard. There were 14 test trials, comprising seven blocks of two trials. Between blocks, sequences increased in length by an increment of one digit. The test was discontinued if participants responded incorrectly to both items in a block. The score was the number of correctly recalled digit sequences.

## **2. Grammaticality judgment**

We based our stimuli on previous work by Hubers, Snijder, and de Hoop (2016), which focused on the perception of prescriptive grammatical norm violations in Dutch. For that study, they pre-tested several hundred sentences containing violations of five prescriptive norms. We thus had access to grammaticality ratings from an educationally diverse sample ( $n=97$ ; aged 18-35). We excluded one type of violation that was only relevant to written language, and calculated

difficulty scores for items in the remaining four categories: *als/dan*; *mij/ik*; *hun/ze*; *die/dat*. As the goal was to develop a task challenging enough to yield a spread of scores, we selected the eight lowest-scoring items from each category, after outliers were excluded. Item scores in the final shortlist ranged from 0.50 to 0.94, with *die* constructions scoring the highest, and *hun* constructions the lowest.

For each category of norm violation, we devised eight control sentences featuring prescribed usage of the relevant critical word; *als*, *mij*, *hun*, or *die* (see Table 1). The resulting 64 critical sentences were matched for syllable length, critical word position, as well as the frequency and prevalence of lexical items. Given the evident uncertainty amongst many native speakers of Dutch regarding the prescribed usage of these forms, we expected to see inaccuracy, both in the rejection of sentences that adhered to grammatical norms, and acceptance of sentences that violated them.

Critical word	Norm violation	Control
<i>hun</i>	Vorige week liepen hun naar de speeltuin. [Last week they walked to the playground]	Gisteren heb ik hun twee boeken gegeven. [Yesterday I gave them two books]
<i>als</i>	De jongen eet minder als zijn grote neef. [The boy eats less as his big cousin]	Zij is net zo groot als Vera op die hoge hakken. [She is just as tall as Vera in those high heels]
<i>mij</i>	Steven heeft eerder dan mij zijn rijbewijs gehaald. [Steven got his driving licence earlier than me]	Hij vindt Linda aardiger dan mij maar niet grappiger. [He finds Linda kinder than me but not funnier]
<i>die</i>	Is er een bureau die voor mij bedoeld is? [Is there a desk that* is meant for me?]	Kent Kees een supermarkt die nog goedkoper is? [Does Kees know a supermarket that is even cheaper?]

**Table 1.** Example items from each category of norm violation with matched control sentences. \*Norm violation does not translate because there is no grammatical gender marking in English.

In addition, we generated 16 filler sentences, half of which were “truly ungrammatical”, featuring syntactic anomalies consistently detected by Dutch native speakers, e.g., errors relating to subordinate clause word order, or verb tense and number agreement. These unambiguous filler sentences allowed us to ensure that participants were not responding randomly.

Stimuli were recorded by a female native speaker of Dutch, using a Sennheiser ME64 microphone. The speaker was instructed to maintain natural, conversational speech rate and prosody across all items.

All 80 items were presented to all participants in one, pseudo-randomised list, such that no more than three correct or incorrect items appeared consecutively. A maximum of two consecutive sentences could contain the same critical word, but they always contrasted in terms of grammaticality. The task began with two filler trials, one ungrammatical. A full stimulus list is provided in the online supplementary materials.<sup>3</sup>

### 3. Syntactic priming

We selected 10 alternating dative verbs that have previously yielded syntactic priming effects in Dutch (Hartsuiker et al., 2008; Bernolet & Hartsuiker, 2010; Bernolet et al., 2016). We used these target verbs to generate 10 subject-verb sentence stems (e.g., *Hij geeft* [He gives]; *Ze overhandigt* [She hands over]), which could be completed using either a PO or DO dative construction. The gender of the subject pronoun was balanced across items, with 50% of sentence stems using *ze* [she].

From the MultiPic database (Duñabeitia et al., 2017), we selected colour pictures of 10 inanimate and 10 animate nouns, matched for Log10 word frequency (SUBTLEX-NL; Keulers et al., 2010), syllable length, picture naming agreement and visual complexity. We used the two sets of pictures to generate

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<sup>3</sup> Stimuli for both experimental tasks, as well as the data, and other further analyses are available in the supplementary materials on [https://osf.io/eg7pw/?view\\_only=56ebe093366943bfb3e6f3eb995c4fac](https://osf.io/eg7pw/?view_only=56ebe093366943bfb3e6f3eb995c4fac)

30 different theme-recipient pairs and assigned each pair to one of the 10 target sentence stems. We conducted a Google Books search to ensure that the transitional probabilities of target verb and animate/inanimate noun combinations were matched within items.

For each target item we constructed five prime sentences, corresponding to the following prime conditions: a) PO Same Verb; b) DO Same Verb; c) PO Different Verb; d) DO Different Verb; e) Baseline (see Figure 1).

- |   |                          |
|---|--------------------------|
| a) Ze schenkt een piano aan de priester.<br>[She gives a piano to the priest.]    | <i>PO Same Verb</i>      |
| b) Ze schenkt de priester een piano.<br>[She gives the priest a piano.]           | <i>DO Same Verb</i>      |
| c) Ze bezorgt een piano aan de priester.<br>[She delivers a piano to the priest.] | <i>PO Different Verb</i> |
| d) Ze bezorgt de priester een piano.<br>[She delivers the priest a piano.]        | <i>DO Different Verb</i> |
| e) De priester speelt piano.<br>[The priest plays piano.]                         | <i>Baseline</i>          |



 Hij schenkt [he gives]...  
 ...een hoed aan de piraat  
 [a hat to the pirate]  
 ...de piraat een hoed  
 [the pirate a hat]

**Figure 1.** Example prime sentences (a – e) with corresponding target picture, sentence stem, and expected completions. *Schenken* means “to give” (as in a gift).

We selected a separate set of 10 inanimate and 10 animate pictures from the MultiPic database, which provided 30 unique combinations of prime themes and recipients. Prime sentences in conditions (a) and (b) repeated the 10 target verbs. For prime conditions (c) and (d), we selected 10 additional alternating dative verbs, on the basis of corpus and experimental data (Colleman, 2009; Colleman & Bernolet, 2012; more detail provided in the online supplementary materials). For the baseline condition (e), we combined monotransitive and intransitive verbs with the same set of nouns, to generate sentences that were syntactically unrelated to the dative. Like the target stems, all dative prime sentences featured *hij* or *ze* as the agent of the dative action. The gender of the pronoun alternated between prime sentences and their corresponding target stems.

Auditory stimuli were recorded by a female Dutch native speaker, using a Sennheiser ME64 microphone. To create the set of target stems, we recorded both PO and DO versions of the complete dative sentences and cut them down using Praat software (Boersma & Weenink, 2017). This resulted in two versions of the same sentence stem for each of the 10 target verbs. We counterbalanced the PO and DO versions across target items, to reduce any differential influence of prosodic cues on participants' syntactic choices.

We constructed 90 filler items that were syntactically and semantically unrelated to experimental items. To reduce the saliency of the dative alternation, filler sentences varied in structure. 70 were simple transitives and intransitives in the present tense; 20 were complex sentences with a complement clause in the past tense, e.g., *Hij zei dat het hemd werd gestreken* [He said that the shirt was ironed]. As auxiliary-participle word order is reversible in Dutch subordinate clauses, we constructed a set of complex sentences using both word orders, counterbalanced across experimental lists. Filler trials followed the same two-part structure as experimental trials: a) sentence comprehension (picture verification) and, b) sentence completion (picture description). For the purposes of the cover task, 60% of items in the verification set featured a semantic mismatch between the sentence stimulus and the content of the visual display. For example, in one incongruent filler trial, participants saw a display with a man and a glass of milk and heard the sentence *De man drinkt koffie* [The man drinks coffee]. All dative trials were congruent.

The picture description set comprised non-critical pictures and corresponding sentence stems that would be unlikely to elicit a dative construction, e.g., *De vrouw draagt* [The woman wears]. The precise format of elicitation varied, depending on the type of filler. For example, where participants were required to complete a sentence with a verb phrase or noun phrase, they heard part of the target phrase immediately before the sentence stem was presented, e.g., *Rode. Hij slaapt in een...* [Red. He sleeps in a...], or *Geslapen. Ze zei dat de koala...* [Slept. She said that the koala...]. Participants were familiarised with the different types of fillers through practice trials at the start of the priming experiment.

We constructed five pseudo-randomised lists of critical stimuli, such that across the lists every item appeared once in each of the five experimental conditions. To give a more reliable measure of participants' structural biases when not primed, we included six additional items in the neutral baseline condition, bringing the total number of dative trials to 36. These were interleaved with the 90 filler items, creating five lists of 126 trials, which we presented in a pseudo-random order such that each dative trial was preceded by at least two filler trials.

### *Procedure*

Participants attended two individual sessions within the same week, each lasting approximately one hour. The first session consisted of the syntactic priming experiment, followed by the grammaticality judgment task. In the second session, participants completed the following sequence of tasks in the same order: Een Minuut Test; Klepel Test; Backward Digit Span; Letter Comparison; PPVT; Misspelling Detection Test; RPM; Author Recognition Test; Reading Habits Questionnaire. Computerised tasks were carried out on a PC in a soundproofed experiment booth at the Max Planck Institute, or on a laptop in a reserved quiet room in the public library. Participants completed the remaining tasks at a desk, under the supervision of the experimenter. Alternating between computerised and non-computerised activities was intended to help sustain attention levels and balance task demands.

The grammaticality judgment task was carried out on a PC or laptop, with auditory stimuli presented via headphones. Participants were instructed to listen

to each sentence and respond to the question, *Is dit een correcte Nederlandse zin?* [Is this a correct Dutch sentence?], by pressing ‘1’ or ‘0’ on the keyboard (for yes and no respectively), and to guess if they were unsure. Each sentence was presented once, along with a visual prompt showing ‘ja = 1’ on the left of the screen and ‘nee = 0’ on the right. There was no time limit on responses and no feedback given. As soon as a button press was recorded, the screen “Volgende zin” appeared and the next trial began. The typical task duration was 10-15 minutes.

The syntactic priming experiment began with written instructions, followed by a series of examples to illustrate the verification task and demonstrate how sentence stems were to be completed in the picture description part of the trial. These demonstrations featured pre-recorded responses from a Dutch native speaker. Half of the example dative trials used PO target completions, and half used DO, so that participants’ exposure to the two structures was balanced before beginning the priming experiment. The dative example trials were interleaved with transitive filler examples to reduce the saliency of the dative alternation. Pilot testing indicated that such a demonstration was necessary to ensure that experimental stimuli reliably elicited dative responses. The passive demonstration phase was followed by four active practice trials, which were semantically and syntactically unrelated to the subsequent experimental trials.

At the start of each trial, participants saw a fixation cross, followed by a pair of pictures, positioned in the lower left and upper right corner of the visual display (as illustrated in Figure 1). The position of the animate and inanimate pictures on the screen was counterbalanced across all items and randomised within each experimental list. Participants then heard a pre-recorded prime sentence that referred to the displayed pictures. As a cover task, they were instructed to press ‘1’ or ‘0’ on the keyboard to indicate whether the content of the sentence and the picture were, respectively, congruent or incongruent. Participants received immediate on-screen feedback: “Correct!” or “Helaas, volgende keer beter!” (Better luck next time!) In the case of a correct response, the feedback screen also displayed reaction time in milliseconds (intended to increase motivation and engagement with the task). The second part of the trial comprised a new visual display with two target pictures (semantically unrelated



to the prime pictures), and an auditorily presented dative sentence stem. Participants completed the sentence aloud with either a PO or DO construction by naming the theme and recipient displayed. To reduce any influence of looking bias on their syntactic choices, participants had a 1000ms preview of the visual display before they heard the target sentence stem. Responses were recorded via a microphone attached to the headset.

## Results<sup>4</sup>

### *Scoring*

Correct responses in the grammaticality judgment task were coded as ‘1’ and incorrect responses as ‘0’.

Responses in the syntactic priming experiment were manually coded as prepositional-object datives (PO), double-object datives (DO), or Other. A response was coded as PO if the theme of the action was supplied first, followed by the preposition *aan* [to], and the recipient (e.g., after the target stem *Hij schenkt* [He gives] in Figure 1, *een hoed aan de piraat* [a hat to the pirate]). A response was coded as DO if the recipient was supplied first with no preposition, followed by the theme of the action (e.g., after the same target stem, *de piraat een hoed* [the pirate a hat]). Non-dative responses were coded as Other.

### *Descriptive summary of individual difference measures*

Means, standard deviations and ranges for each measure are reported in Table 2, as well as a descriptive summary of age. Correlations among the individual difference measures can be found in the online supplementary materials (Table S2).

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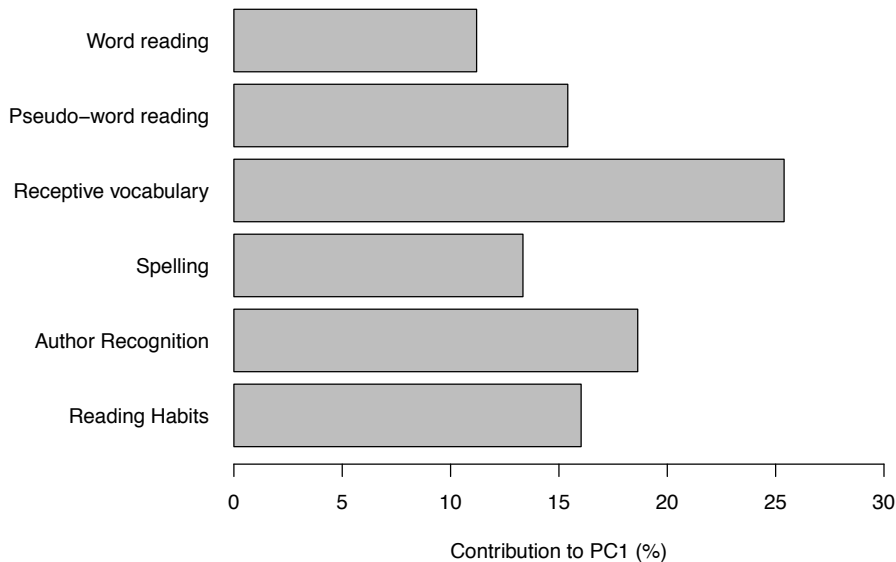
<sup>4</sup> To interpret our results, we adopt a magnitude estimation approach where applicable, in line with recommendations that the field should be shifting focus away from significance testing, towards estimation based on effect sizes and confidence intervals instead (Cumming, 2013; see also Huettig & Janse, 2016; Hintz et al., 2017).

Measure	Mean	SD	Range	Max
<i>Literacy-related abilities</i>				
1. Word reading (Een minuut)	94.68	14.60	56–116	116
2. Pseudo-word reading (Klepel)	104.90	9.83	77–116	116
Klepel 1 min	65.69	10.76	40–94	116
3. Vocabulary (PPVT)	101.20	10.56	74–128	139
PPVT percentile rank	53.18	23.73	4–97	100
4. Misspelling detection	18.66	1.37	14–20	100
5. Author recognition	8.12	7.74	0–50	60
6. Reading habits questionnaire	80.04	8.88	41–105	114
<i>General cognitive abilities</i>				
7. Non-verbal IQ (RPM)	19.72	5.91	5–32	36
8. Processing speed (LC)	1076	192	673–1644	–
9. Working memory (BDS)	7.90	2.15	2–13	14
10. Age (years)	23.41	3.44	18 –34.58	35

**Table 2.** Means, standard deviations, ranges, and maximum possible scores for the individual difference measures. N = 148. Max = Maximum possible score; PPVT = Peabody Picture Vocabulary Test; RPM = Raven’s Progressive Matrices; LC = Letter Comparison task; BDS = Backward Digit Span task.

### *Principal components analysis*

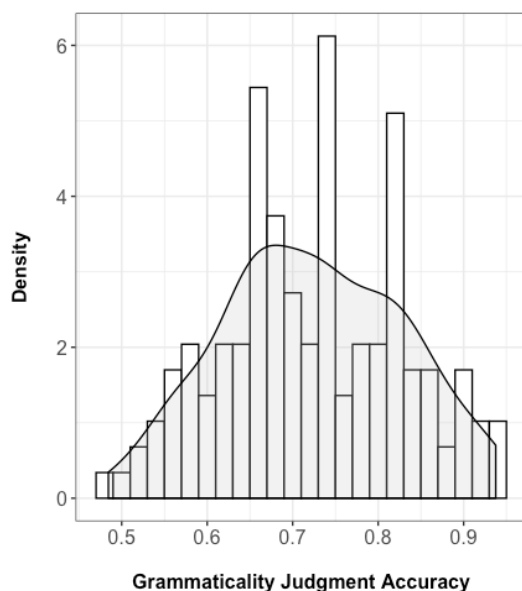
Our test battery targeted a range of skills involved in literacy (measures 1–6 in Table 2). Using the *FactoMineR* package in R (Lê et al., 2008; R Core Team, 2012), we performed principal components analysis on this subset of variables to derive an underlying construct that explained the maximal amount of variance in the literacy data. The *FactoMineR* package contains a built-in function to evaluate the intercorrelation of variables with respect to a pre-defined criterion. The analysis extracted six principal components, of which the first explained 37.7% of the variance in the data. The composition of the first principal component is shown in Figure 2. All six literacy-related measures make some contribution, most of all receptive vocabulary (measure 3, Table 2) at 25%. We use the first principal component score as an index of literacy experience (predictor variable) in the main analyses, since it explains the largest portion of variance in literacy-related skills. Further details about the other five principal components can be found in the online supplementary materials.



**Figure 2.** Bar plot showing the contribution of individual variables to the first principal component for literacy (PC1).

### *Grammaticality judgment*

Descriptive statistics on the grammaticality judgment task were 0.72 (mean), 0.11 (standard deviation), 0.72 (median), and 0.48–0.94 (range). Consistent with the equal mean and median values, the plot in Figure 3 reflects a fairly symmetrical distribution of scores across the sample. Only one participant performed below chance, and while mean accuracy on the task was relatively high, nobody scored at ceiling.

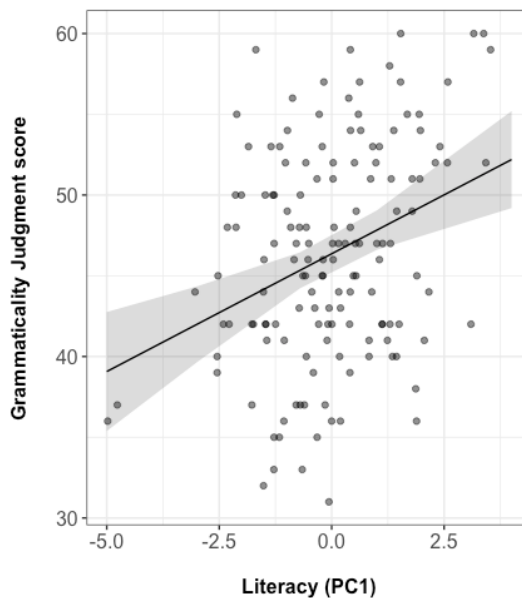


**Figure 3.** Histogram of grammaticality judgment accuracy with a plotted density curve.

### *Literacy and grammaticality judgment*

We used multiple linear regression analysis to address our research question: Are individual differences in literacy associated with the identification of grammatical norm violations in spoken language? The approach (*lm* in R) enabled us to evaluate literacy experience as an independent predictor of grammaticality judgment, while controlling for the contribution of general cognitive abilities. Scores on the RPM, backward digit span, and letter comparison task were entered into the model as covariates, with literacy score as

a predictor. The fitted model with an  $R^2$  of .211 revealed an independent contribution of literacy to participants' grammaticality judgment accuracy (unstandardised  $\beta = 1.459$ ,  $SE\beta = .358$ , 95% confidence interval [.756, 2.161], standardised  $\beta = .328$ ). The standardised beta represents a measure of effect size, roughly equivalent to Pearson's  $r$ . The scatterplot in Figure 4 shows the relationship between literacy experience and grammaticality judgment (the line for the model above is fitted to the data).



**Figure 4.** Scatterplot showing the relationship between literacy and grammaticality judgment. The line represents the regression fit from the model of judgment accuracy as a function of literacy score, controlling for the contribution of general cognitive abilities ( $R^2 = .211$ , effect size = .328). Dependent variable is raw score in the grammaticality judgment task (scored out of 64). PC1 = First principal component.

We also carried out an exploratory analysis to assess the contribution of primary versus secondary influences of reading (Huettig & Pickering, 2019) to the observed literacy effect on grammaticality judgments. Secondary influences can also arise from listening to ‘book-like’ auditory materials, such as

audiobooks. This is because ‘book language’ contains syntactically more elaborate language (with higher demands on verbal memory) and more extensive and sophisticated vocabulary than conversational speech. Primary influences are those that are more directly linked to the physical act of reading (e.g., efficient decoding of written language; increased exposure to the extreme form-invariance of printed word forms; parallel processing of multiple letters/words in proficient readers; see Huettig & Pickering, 2019, for further discussion).

Our broad-based battery tested a range of skills related to reading, which were distilled into an underlying ‘literacy’ construct through principal components analysis. Within the first principal component, the literacy-related measures were not all equally weighted (Figure 2). In order to pull apart ‘primary’ and ‘secondary’ influences of reading, we conducted an exploratory analysis which modelled these separately. First, we performed principal components analysis on a subset of the literacy data: word reading, pseudo-word reading and spelling, which we took to reflect primary characteristics of reading. The first principal component (PC1) accounted for 52.1% of the variance across these three measures. Next, we modelled grammaticality judgment accuracy as a function of this new ‘primary’ literacy variable (PC1), relative to the ‘secondary’ characteristics of literacy – vocabulary and verbal working memory. In addition, we included ART score as a predictor, since knowledge of author names can also be considered a secondary characteristic of literacy. Finally, the control measures, non-verbal IQ and processing speed were added to the model as co-variates.

The results of the exploratory multiple regression analysis are summarised in Table 3. Standardised  $\beta$  estimates are reported as a measure of effect size. Vocabulary made the largest independent contribution to grammaticality judgment accuracy (standardised  $\beta = .33$ ), followed by verbal working memory (standardised  $\beta = .19$ ). The effect of author recognition was small (standardised  $\beta = .15$ ), comparable to that of processing speed (.14). Notably, we did not find evidence for a main effect of primary literacy characteristics (PC1) on grammaticality judgment accuracy (standardised  $\beta = -.03$ ). These exploratory results suggest a dissociation between primary and secondary influences of reading in our data. When it comes to metalinguistic syntactic abilities,

vocabulary size and verbal working memory seem to matter more than being a fast decoder or an accurate speller.

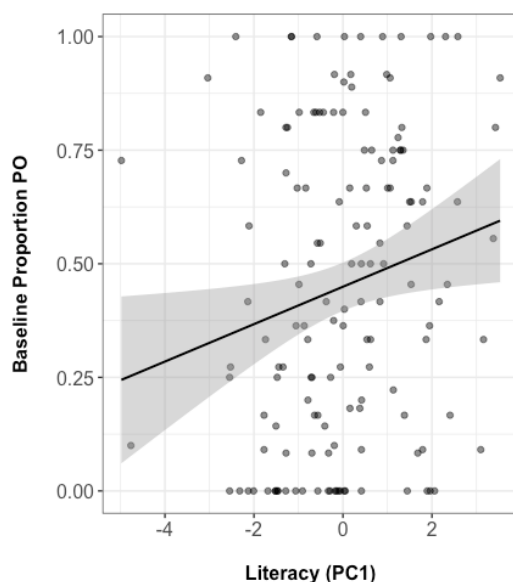
Variable	Standardised $\beta$ estimate	95% CI
Primary literacy (PC1)	-0.03	-0.20, 0.14
Vocabulary	0.33	0.14, 0.52
Author recognition (ART)	0.15	-0.01, 0.32
Verbal working memory	0.19	0.03, 0.35
Non-verbal IQ	-0.05	-0.21, 0.12
Processing speed	0.14	-0.02, 0.29

**Table 3.** Results of exploratory multiple linear regression analysis. Dependent variable: Grammaticality Judgment score. CI = Confidence Interval.

### *Syntactic priming*

Participants produced 2499 PO responses (43.1%), 2894 DO responses (49.9%), and 403 Other responses (6.9%). To evaluate the consistency of priming behaviour *within* individuals, we conducted a split-half reliability analysis. For subsets of even and odd trials separately, we calculated the proportion of PO responses as a function of prime condition for each participant. The PO proportions for the two subsets were then correlated to provide a measure of within-participant consistency. The split-half correlation magnitude was  $r = .66$  (Kendall's  $\tau = .56$ ), suggesting that priming behaviour was moderately consistent at the individual level.

We first explored whether literacy was associated with a bias towards PO or DO dative constructions, in line with our speculation that written language experience might affect the usage of structural alternates. Figure 6 shows that higher literacy scores were somewhat associated with producing a PO dative following a neutral baseline sentence (correlation coefficient Kendall's  $\tau = .19$ ). This is consistent with the notion that literacy experience shapes the (baseline) usage of PO or DO dative constructions.



**Figure 6.** Literacy score plotted against proportion of POs produced in the baseline condition. PC1 = First principal component.

Table 4 reports the proportion of POs and DOs out of all datives produced in each priming condition (excluding Other responses). The baseline proportions shown in Table 4 reflect the overall bias towards DO datives observed in this experiment (cf. Bernolet et al., 2016). The likelihood of producing a PO dative following a neutral baseline sentence was 45%. This increased to 51% when a PO prime was presented, resulting in a 6% priming effect in the absence of any lexical overlap between prime and target. When prime and target verbs were the same, there was a 62% chance of a PO response following a PO prime (17% priming effect). The 11% change in priming magnitude as a function of verb overlap demonstrates a lexical boost effect (see also the interaction between prime structure and verb condition shown in Table 5). DO datives showed weaker priming and lexical boost effects. Compared to baseline, the chance of a DO response was 4% higher in the different verb priming condition, and 10% higher in the same verb condition, indicating a 6% lexical boost.



	Proportion PO	Proportion DO
Baseline	0.45	0.55
PO Different Verb	0.51	0.49
PO Same Verb	0.62	0.38
DO Different Verb	0.41	0.59
DO Same Verb	0.35	0.65

**Table 4.** PO and DO responses as a proportion of datives produced in the different priming conditions.

We fit a linear mixed effects logistic regression model to participants' responses across conditions, in line with the current standard for analysing categorical data (e.g., Barr et al., 2013; Jaeger, 2008). We used the *lme4* package in R version 1.0.153 (Bates et al., 2015; R Core Team, 2012) to create the model, which predicts the logit-transformed likelihood of a PO response (see Table 5). PO responses were as coded as '1' and DO responses were coded as '0' (other responses were excluded from this analysis). The first model comprised three fixed effects: Prime Type (Baseline/Dative), Prime Structure (PO/DO), and Verb Condition (Same/Different). We used contrast coding to capture the nested design, whereby structure and verb condition were manipulated within the dative primes only (not the baseline primes). In addition, we were interested in the interaction between Prime Structure and Verb Condition (i.e., the lexical boost effect). The model included random intercepts for participants and target verbs, as well as a random effect of Prime Structure by participant and by target verb, and a random effect of Verb Condition by participant. We assumed that the priming effect would be influenced to varying degrees by individual target verbs' PO- or DO bias, hence the inclusion of target verb in the model's random effects structure. All random effects were de-correlated. Model results are summarised in Table 5.

Predictor	Coefficient	SE	z value	CI
Intercept	-0.30	0.24	-1.25	-0.78, 0.17
Prime Type (Dative)	0.00	0.12	0.01	-0.23, 0.24
Prime Structure (PO)	1.27	0.10	12.68	1.07, 1.46
Verb Condition (Same)	0.18	0.09	1.92	-0.00, 0.36
Interaction = <i>Prime Structure &amp; Verb Condition</i>	1.20	0.19	6.35	0.83, 1.58

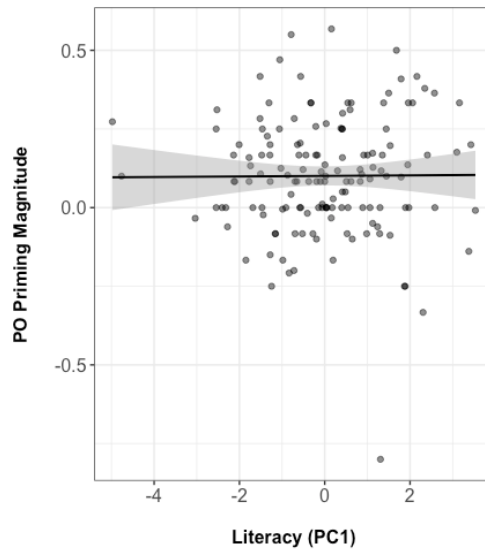
**Table 5.** Summary of fixed effects in the mixed logit model (N = 4984, log-likelihood = -2425.7). The intercept represents the grand mean log-odds of a PO response, averaged across conditions. SE = Standard Error; CI = Confidence Interval.

Table 5 reveals a large syntactic priming effect (Prime Structure,  $z = 12.68$ ). It also reveals a robust lexical boost effect (*Prime Structure & Verb Condition*,  $z = 6.35$ ). These data therefore reflect a successful replication of the syntactic priming phenomenon (including the lexical boost effect) in a large, community-based sample of Dutch native speakers with varying literacy levels.

#### *Literacy and syntactic priming*

Figure 7 plots literacy score against priming magnitude (calculated as raw number of POs in PO prime condition minus POs at baseline). It shows that literacy did not modulate syntactic priming.

We fit another mixed logit model to participants' responses, this time incorporating Literacy (first principal component score) as a continuous predictor variable. The model results are summarised in Table 6.



**Figure 7.** Literacy score plotted against priming magnitude (calculated as raw number of POs in PO prime condition minus POs at baseline). Correlation coefficient, Kendall’s  $\tau = .081$ .

Predictor	Coefficient	SE	z value	CI
Intercept	-0.30	0.24	-1.27	-0.77, 0.16
Prime Type (Dative)	0.00	0.12	0.01	-0.23, 0.24
Prime Structure (PO)	1.26	0.10	12.67	1.07, 1.46
Verb Condition (Same)	0.18	0.09	1.95	0.00, 0.36
Literacy	0.28	0.12	2.43	0.05, 0.51
Interaction = <i>Prime Structure &amp; Verb Condition</i>	1.19	0.19	6.32	0.82, 1.56
Interaction = <i>Prime Structure &amp; Literacy</i>	0.00	0.07	-0.05	-0.13, 0.12

**Table 6.** Summary of fixed effects in the mixed logit model (N =4984, log-likelihood = -2422.8). The intercept represents the grand mean log-odds of a PO response, averaged across conditions. SE = Standard Error; CI = Confidence Interval.

Table 6 reveals a large syntactic priming effect (Prime Structure,  $z = 12.67$ ), which was not modulated by participants' literacy skills (*Prime Structure & Literacy*,  $z = -0.05$ ). Interestingly, the model shows that higher literacy scores were associated with a greater tendency to produce PO constructions in general (Literacy coefficient,  $z = 2.43$ , i.e., a main effect of literacy on the log-odds of a PO response, averaged across conditions). This adds to the finding that literacy experience increases usage of PO dative constructions following a neutral baseline sentence (Figure 6). In other words, in our large sample ( $N=161$ ) of participants with varying literacy levels, we observed that literacy experience affects the usage of alternating PO/DO datives in Dutch yet does not modulate the syntactic priming of these constructions.

## Discussion

We investigated the contribution of individual differences in literacy experience to syntactic processing in spoken language. We administered a battery of tests to assess a range of literacy-related skills and general cognitive abilities and used two experimental tasks, grammaticality judgment and syntactic priming, to target offline and online syntactic processes respectively.

### *Grammaticality judgment*

Violations of four Dutch grammatical norms were tested. We observed systematic variation across individuals in their accuracy on the grammaticality judgment task. Above and beyond the contribution of general cognitive abilities, literacy uniquely predicted participants' ability to correctly accept and reject spoken sentences according to the prescriptive grammatical norms of their language. Controlling for the contribution of general cognitive abilities, we observed a robust effect of literacy experience on the detection of grammatical norm violations in spoken sentences, suggesting that exposure to written language has specific benefits for general (modality-independent) syntactic knowledge. This result converges with and extends previous findings concerning the relationship between print exposure and syntactic abilities (Dąbrowska, 2012;

Street & Dąbrowska, 2010). The current study used a multi-faceted measure of literacy experience and found a moderate positive correlation with metalinguistic syntactic abilities, adding evidence to support the link between language experience and aptitude in adult native speakers. The finding is consistent with the notion that exposure to the syntactic complexity and diversity of written language enhances syntactic knowledge, such that more reading leads to better syntactic abilities.

In line with the association between vocabulary size and written language experience, we had pre-registered the prediction that vocabulary knowledge would be positively correlated with accuracy in grammaticality judgments. We also conducted an exploratory re-analysis of the other individual tests associated with literacy to examine the possible contribution of primary and secondary influences of print exposure (Huettig & Pickering, 2019) to grammaticality judgment. We considered as a possible source of primary influence, skills developed through the physical act of reading (word reading, pseudo-word reading, and spelling). Vocabulary and verbal working memory, which improve as an indirect consequence of reading, were considered individually as possible secondary influences on grammaticality judgment. We found that both vocabulary and verbal working memory were better predictors of task performance than a composite of the primary literacy measures. The literacy effect on grammaticality judgment in our study thus appears to be more secondary in nature, likely originating from exposure to ‘book language’ as opposed to physical reading practice.

From an experience-based perspective, we had a straightforward prediction about the effect of literacy experience on grammaticality judgment accuracy. The task was to judge the ‘correctness’ of spoken sentences, with reference to prescriptive norms that are attested in written texts far more reliably than in spoken language. Therefore, on the basis of differences in the quantity and quality of the input, frequent readers should have more relevant data to support their judgments.

When considered as a measure of explicit syntactic awareness, grammaticality judgment requires the caveat that the contribution of some implicit syntactic knowledge to task performance cannot be ruled out. Given that no

psycholinguistic task is ‘purely’ explicit or implicit, and that participants in grammaticality judgments are explicitly asked to make a judgment, we can however be reasonably confident that grammaticality judgments involve more explicit processing than the syntactic priming task, which merely requires participants to complete sentences (and does not explicitly draw attention to the purpose of the task).

### *Syntactic priming*

We successfully replicated the most well-documented effects in the syntactic priming literature. Using comprehension-to-production priming of the dative alternation in Dutch, we observed a statistically large syntactic priming effect and a robust lexical boost effect in a community-based sample of native Dutch speakers with varying literacy levels.

Within our large sample (N=161), there was considerable individual variability in syntactic priming behaviour, with many participants showing no priming at all, and others showing a negative effect. Individual differences have been given little attention in the syntactic priming literature to date (cf. Kidd, 2012). There is a tendency to consider effects only at the group level and to dismiss the absence of priming as experimental noise. Gathered from a large and diverse sample (with respect to ability), our data suggest that between- and to some extent within-participant variability may be the norm rather than the exception for syntactic priming.

The large syntactic priming effect we observed was not modulated by participants’ literacy skills. Importantly, this absence of modulation of the priming effect was not due to an absence of differences in structure *use*. Our model revealed that higher literacy scores were associated with a greater tendency to produce PO constructions in general. Moreover, literacy experience was associated with an increased usage of PO dative constructions following a neutral baseline sentence. We therefore conclude that literacy experience affects the usage of alternating PO/DO dative constructions in Dutch but does not modulate their syntactic priming (nor the lexical boost).

We had predicted a negative correlation between literacy experience and priming magnitude, motivated by the notion that literacy-related differences in

usage of the dative alternation would affect syntactic priming of the alternates. This hypothesis was not supported. One possibility is that literacy-related usage differences only play a role in syntactic priming during language *acquisition* but (more or less) ‘level off’ in proficient language users such as the adults who took part in the present study. Future large *N* studies could usefully explore this possibility. If it was the case that our adult participants had reached a plateau in the acquisition of basic syntactic structures, regardless of literacy level, a developmental study may be a fruitful alternative for exploring the influences of literacy on syntactic priming at an earlier stage of acquisition.

In our experiment, PO datives were produced less frequently than DO datives overall yet yielded a larger priming effect. Previous studies have shown that infrequent structures tend to prime more reliably, consistent with the idea that the unexpectedness of the prime structure has a bearing on the strength of priming (i.e., more frequent/predictable structures are assumed to prime less than relatively infrequent/unpredictable structures – the so-called inverse preference effect). Our measure of participants’ PO/DO preference following a non-dative prime (baseline condition) allowed us to test this assumption. We conducted an exploratory analysis that revealed a marginal negative effect of PO preference on PO priming, suggesting a small tendency in the predicted direction.<sup>5</sup> However, given the large sample size, our data do not provide robust evidence for the inverse preference effect, as has been reported elsewhere in the literature (e.g., Jaeger & Snider 2013). Given that other (often unpublished) studies have failed to observe the inverse preference effect (e.g., Kaschak & Borreggine, 2008), future research could be directed at exploring which factors modulate the presence and absence of this effect in syntactic priming experiments.

One explanation for the present data might be that the absence of a modulation of priming magnitude by literacy was simply a null effect in a study that failed to detect a ‘real’ effect. However, we consider such an interpretation unlikely, given our large, community-based sample (i.e., varying in literacy level) and carefully selected literacy tests. Another suggestion might be that corpus measures would have provided a better estimate of PO/DO usage in spoken and written Dutch.

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<sup>5</sup> For details of further analyses, see the online supplementary materials: [https://osf.io/eg7pw/?view\\_only=56ebe093366943bfb3e6f3eb995c4fac](https://osf.io/eg7pw/?view_only=56ebe093366943bfb3e6f3eb995c4fac)

We conjecture that measuring PO/DO usage directly with a baseline as in the present study is a more reliable way of assessing influences of literacy. Note that Dutch corpora (Haemers, 2012; Coleman, 2009) and experimental baseline data (e.g., Bernolet et al., 2016) are often inconsistent with respect to PO/DO distribution (Hartsuiker, personal communication). This may be because Dutch corpora and experimental samples both tend to be small in size and prone to bias. It is noteworthy, for instance, that the overall distribution of PO and DO datives in our data was quite different to previous Dutch priming studies (e.g., Bernolet et al., 2016). We found DO to be marginally the more frequent construction, in contrast to the strong PO preference previously reported by Bernolet and colleagues. This divergence likely reflects differences in sample size but also in the populations sampled: In our study, highly experienced literates, like Bernolet's undergraduate participants, did demonstrate an overall PO bias, while less experienced literates tended to produce more DO datives.

### *Conclusion*

We conducted a large-scale correlational study with 161 adult native speakers of Dutch, to examine literacy experience as a predictor of syntactic processing in spoken language, controlling for the contribution of general cognitive abilities (non-verbal IQ, verbal working memory, and processing speed). As predicted, we found an effect of literacy experience on syntactic awareness, specifically the detection of grammatical norm violations in spoken sentences. Literacy was also associated with increased usage of prepositional-object datives in spoken sentences but, contrary to our prediction, had no detectable effect on their implicit syntactic priming in our adult sample. This suggests that syntactic priming is not modulated by *life-long* syntactic experience, at least in proficient language users.





### **3. Are there core and peripheral syntactic structures? Experimental evidence from Dutch native speakers with varying literacy levels<sup>6</sup>**

Some theorists posit the existence of a ‘core’ grammar that virtually all native speakers acquire, and a ‘peripheral’ grammar that many do not. We investigated the viability of such a categorical distinction in the Dutch language. We first consulted linguists’ intuitions as to the ‘core’ or ‘peripheral’ status of a wide range of grammatical structures. We then tested a selection of core- and peripheral-rated structures on naïve participants with varying levels of literacy experience, using grammaticality judgment as a proxy for receptive knowledge. Overall, participants demonstrated better knowledge of ‘core’ structures than ‘peripheral’ structures, but the considerable variability within these categories was strongly suggestive of a continuum rather than a categorical distinction between them. We also hypothesised that individual differences in the knowledge of core and peripheral structures would reflect participants’ literacy experience. This was supported only by a small trend in our data. Thus, lay people’s intuitions dovetail overall with linguists’ classifications of ‘core’ and ‘peripheral’ grammar, but suggest a continuum of prevalence. The results fit best with the notion that more frequent syntactic structures are mastered by more people than infrequent ones and challenge the received sense of a categorical core-periphery distinction.

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<sup>6</sup> Adapted from Favier, S. & Huettig, F. (in press) *Are there core and peripheral syntactic structures? Experimental evidence from Dutch native speakers with varying literacy levels.*

## Introduction

A strong claim of generative linguistics is that all members of a language community converge on the same internal grammar (Chomsky, 1965; Crain & Lillo-Martin, 1999; Lidz & Williams, 2009; Nowak et al., 2001). Related to this (but not exclusive to the generative tradition) is the notion of ‘core grammar’, an inventory of structures acquired by virtually all native speakers. Properties of the standard language that are absent from this collective body of knowledge are described by some theorists as ‘peripheral’ (e.g., Broekhuis & Keizer, 2012; Broekhuis, 2016). Whereas ‘core’ phenomena are hypothesised to “arise spontaneously in the language-learning child”, those on the ‘periphery’ must be “consciously learned at a later age” (Broekhuis, 2016, p. 298); they are often restricted in register (e.g., formal, written), and may deviate from the rules of the core system (e.g., loan forms). Chomsky (1981; p. 8) for instance argued that core grammar is determined by parameter settings of universal grammar and that there is “a periphery of borrowings, historical residues, inventions, and so on, which we can hardly expect to – and indeed would not want to – incorporate within a principled theory of UG.”

The theoretical core-periphery dichotomy is not without its critics and has been strongly questioned (Culicover, 1999). To our knowledge, however, there have been few attempts to examine ‘core’ and ‘peripheral’ syntactic knowledge empirically in native speaker populations. In a step towards establishing the ‘core’ grammar of Dutch, Hulstijn (2017) collected spoken corpus data showing substantial commonalities in the syntactic patterns produced by a sample of native speakers that was heterogenous in terms of age, education and profession. However, limited conclusions could be drawn about the breadth of participants’ productive knowledge, given the small size of the corpus (Hulstijn, 2017). In the present study we used a different approach to investigate the empirical basis for core and peripheral syntactic structures in Dutch. We first asked Dutch linguists for their intuitions as to the ‘core’ or ‘peripheral’ status of a wide range of grammatical structures in the Dutch language and then asked naïve Dutch participants with varying levels of literacy experience to judge the

grammaticality of a selection of core- and peripheral-rated structures, as a proxy for their receptive knowledge.

Also relevant to the question of core and peripheral syntactic knowledge is the growing body of evidence that demonstrates that adult native speakers do not all master the grammar of their language to the same extent. Challenging a core assumption of generative linguistics, considerable individual differences in native syntactic proficiency have been observed across a variety of structures, tasks, and speaker communities (reviewed by Dąbrowska, 2012, and Dąbrowska & Divjak, 2019).

A key determinant of differences in syntactic proficiency appears to be the degree of experience with written language. Montag and MacDonald (2015), for instance, showed that avid readers' implicit syntactic choices in speech reflected the structural distributions of written language. Wells et al. (2009) found that manipulating written language input to maximise exposure to relative clauses over several weeks boosted processing of the same structure in a subsequent reading task. Dąbrowska (2018) observed a small contribution of print exposure (as measured by Author Recognition; ART) to listeners' comprehension of basic constructions that occur in everyday spoken language. Langlois and Arnold (2020) reported a positive relationship between print exposure (ART) and the use of syntactic cues to interpret ambiguous pronoun reference. Furthermore, Street and Dąbrowska (2010) observed that auditory comprehension of full passives correlated with self-reported hours of reading in adults matched for educational attainment. Finally, the detection of prescriptive grammatical norm violations in spoken Dutch was robustly associated with literacy experience in a large sample of adult native speakers, even after accounting for general cognitive abilities (Favier & Huettig, under review).

The notion that literacy experience shapes syntactic knowledge is compatible with usage-based models of language processing, in which acquisition is largely determined by the quality and quantity of the input a language user receives (e.g., Abbot-Smith & Tomasello, 2006; Bybee 2006). In terms of input quality, 'book language' is syntactically more complex and diverse than conversational speech (Kroll, 1977; Roland et al., 2007). Furthermore, skilled readers read more and thus encounter a larger volume of language, which they process at a faster rate

than listeners can (260 words per minute for English fiction – approximately twice the typical speech rate; Brysbaert, 2019).

Although there is therefore considerable experimental evidence for literacy-related differences in syntactic proficiency, two issues are noteworthy. First, each of the studies discussed above targeted a small number of structures (between one and ten), making it difficult to draw conclusions about the importance of long-term exposure to ‘book language’ for syntactic proficiency in general. Second, no previous research has examined literacy-related individual differences in syntactic knowledge with reference to the notion, borrowed from linguistics, of ‘core’ and ‘peripheral’ grammar.

### *Current study*

Here, we assessed knowledge of 50 syntactic structures in two groups of non-reading impaired adults, sampled from opposite ends of the literacy experience continuum that exists within a literate society like the Netherlands. In addition to examining literacy-related differences, we aimed to provide a snapshot of the breadth of receptive syntactic knowledge that might be shared by the majority of adult native Dutch speakers. We focused on receptive knowledge of structures that had been designated as either ‘core’ or ‘peripheral’ by Dutch linguists during an extensive pre-test of the materials (described in the next section). We assessed participants’ knowledge of these core- and peripheral-rated structures using a grammaticality judgment task. Acceptance of a structure as grammatical when presented in two different sentence contexts was taken as a proxy for receptive knowledge of that structure.

For the present study, we predicted that item-level performance would broadly reflect linguists’ intuitions as to whether a given structure belonged to ‘core’ or ‘peripheral’ grammar. If this is a genuine categorical distinction, we would expect a large discrepancy in accuracy on core- versus peripheral-rated structures. Furthermore, following the usage-based assumption that syntactic knowledge is acquired from the input, we predicted that judgments in general would be subject to considerable individual variation, reflecting individual patterns of experience with language (Kidd et al., 2018). We were specifically interested in written language experience as a determinant of receptive syntactic

knowledge. People of varying literacy levels are likely to have gained adequate exposure to core sentence structures. However, we predicted better accuracy on peripheral structures for highly experienced literates, as a function of prior enhanced print exposure.

## Method

### *Participants*

The thirty-eight native Dutch speakers who participated in the Favier et al. (under review) study also participated in the current study (mean age = 25.2; 25 females). These 38 were recruited from a pool of 161 participants with varying degrees of literacy experience who had completed a battery of individual difference measures as part of a large-scale individual differences study (Favier & Huettig, under review). Principal components analysis was performed on six literacy measures (Peabody receptive vocabulary, author recognition, reading habits, spelling, word and pseudoword reading) to derive an underlying construct that explained the maximal amount of variance in the literacy data (Literacy PC1 in Table S1)<sup>7</sup>. For the Favier et al. (under review) and the current study, all participants in the top and bottom quartiles for Literacy PC1 who responded to our invitation were tested. We refer to these groups respectively as high literacy experience (HLE) and low literacy experience (LLE). There was a pronounced group difference in literacy experience, based on Literacy PC1 ( $t = 8.70, p < 0.001$ ) and ART 2 scores ( $t = 4.01, p < 0.001$ ). The small difference in non-verbal IQ (Raven's) scores between high and low literacy groups ( $t = 2.10, p = 0.04$ ) was expected and is in line with previous research (e.g., Olivers et al., 2014). Note that the sample size ( $N=38$ ) and indeed the participants were thus identical to Favier et al. (under review), a study that observed robust effects of literacy on syntactic processing. Ethical approval was given by Radboud University institutional review board. A descriptive summary of the groups is provided in the Supplementary Materials (Table S1).

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<sup>7</sup> A detailed description of the tests and the principal components analysis, plus grammaticality judgment stimuli, data, and results of additional analyses are provided in the supplementary materials on [https://osf.io/dhqs7/?view\\_only=5bdefd946fe840bd93b4c1ddb0af716a](https://osf.io/dhqs7/?view_only=5bdefd946fe840bd93b4c1ddb0af716a)

### Materials

We systematically extracted 180 grammatical structures from a compendium of Dutch grammar (*Algemene Nederlandse Spraakkunst*; Haeseryn et al., 1997). The selection encompassed a broad range of noun-phrase, verb-phrase, and clause-level structures, and reflected a taxonomy of important grammatical phenomena (e.g., mood), their constituent categories (e.g., conditional), and subtypes (e.g., with inversion). We generated two semantically distinct but syntactically parallel sentences to exemplify each structure.<sup>8</sup> The lexical content of the examples was kept as simple as possible (sentences adapted from *Algemene Nederlandse Spraakkunst* were often reduced in length and complexity). Sentences (a) and (b) are parallel examples of a conditional construction involving inversion (indicated in italics).

a) *Word ik ziek*, zoek dan een vervanger.

If I become unwell, look for a replacement.

b) *Regent het*, dan gaan we niet naar het strand.

If it rains, we won't go to the beach.

We invited expert informants to complete an online pre-test in which they read a randomised sequence of paired examples, such as (a) and (b). Informants were asked to select the best description for each structure from the following options: Core (known by virtually all adult native Dutch speakers); Peripheral (unknown to many native speakers); Incorrect; Unsure. Written instructions at the start of the survey qualified “known” as relating to receptive knowledge. Space for optional additional comments was provided for all structures. To make the duration manageable, we created three versions of the survey, each comprising a different set of 60 structures (i.e. one third of the long list).

Twenty-three expert informants participated in the online pre-test. They were professors, assistant professors, and post-doctoral researchers at six Dutch linguistics faculties in the Netherlands and Belgium. Informants were allocated

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<sup>8</sup> Grammatical phenomena were identified in consultation with Brigitte Bauer, who also advised extensively on the selection of examples for each structure.

in approximately equal proportions to the three versions of the online survey. Pre-testing stopped when the total number of responses collected for each structure reached either seven or nine (i.e. an odd number).

After aggregating the responses by structure, we discarded those identified as incorrect by more than two informants (five structures discarded in total). 95 structures were judged to be “Core” by all respondents. From this list we selected a representative set of 25 test items, comprising four noun phrase, 11 verb phrase, and 10 clause level structures. Because “Peripheral” judgments showed much less agreement overall, we set a lower criterion for inclusion in this category. A structure was included if more than half of respondents judged it to be peripheral; in other words, if it received at least 4/7 or 5/9 “Peripheral” responses. This resulted in a shortlist of 30 peripheral structures, from which we selected 25 test items (six noun phrase, seven verb phrase, and 12 clause-level structures). We avoided structures that were highlighted as archaic in the comments. Detailed information about the shortlisted structures is provided in the online supplementary materials.

In addition to the 50 critical items, we created 15 pairs of ungrammatical sentences as foils. These were comparable to the critical sentences in word length and lexical complexity and were designed to increase the difficulty of the test. Each pair of foil sentences contained parallel syntactic anomalies, concerning a noun phrase, verb phrase, or clause, as shown in (c) and (d).

- c) \*Er wordt geregend.
- d) \*Er werd gewaaid.

As every core, peripheral, and foil item consisted of two sentences, a total of 130 sentence stimuli were presented in the test. Whereas the pre-test featured a succession of sentence pairs, each corresponding to one structure, the main grammar test presented all sentences individually, resulting in 130 trials. The order of presentation was pseudo-randomised such that examples of the same structure were separated by at least two syntactically unrelated sentences. All participants saw the same pseudo-randomised list.



### Procedure

The test was implemented in Frinex, a software packaged developed at the MPI for online experiments. Participants completed the test individually in a quiet room, using a desktop PC and mouse. On each trial, a sentence appeared on the screen followed, after a three-second lag, by two questions and their corresponding response buttons (illustrated in Figure 1). The questions were “Goed Nederlands?” *Good Dutch?* (Ja/Nee response), and “Hoe zeker ben je?” *How certain are you?* (numerical rating scale). The certainty scale was explained in the instructions as follows: 1=geen idee; 2=onzeker; 3=redelijk zeker; 4=zeker. The purpose of the three-second lag was to encourage participants to read the stimulus sentence fully at least once before responding. Only after responding to both questions could they proceed to the next trial, by clicking a button at the bottom on the screen. If no response was recorded, the next trial began automatically after 20 seconds.

Written instructions at the start of the test included five example trials, with Ja/Nee responses completed as appropriate. Two of the examples were foils. The purpose of the example trials was to demonstrate that the question “Goed Nederlands?” entailed a grammaticality judgment, hence calling attention to the syntactic form of the sentences. Participants had the opportunity to seek clarification from the experimenter after reading the instructions. The test took approximately 30 minutes.



**Figure 1.** Illustration of test interface. Participants had 20 seconds to answer both questions.

## Results

137 out of 4940 trials were excluded from the analysis (38 because of a typo in one of the sentences and 99 that timed out before a response was given). The timeout rate was 1.4% in the HLE group and 2.7% in the LLE group. Of the remaining total, 1860 judgments were obtained for core items, 1820 for peripheral items, and 1123 for foil items. Item-level results are summarised below (results for individual structures can be found in the Supplementary Materials). We then consider performance at the participant level and apply inferential statistics to evaluate literacy-related differences in receptive syntactic knowledge.

### Item-level analysis

The overall acceptance rate (i.e., rate of “Ja” responses) was 90.3% on core trials, 56.9% on peripheral trials, and 13.2% on foil trials. Mean certainty (rated on a 4-point scale where 4 = certain) was 3.51 for core items, 3.19 for peripheral items and 3.47 for foil items.

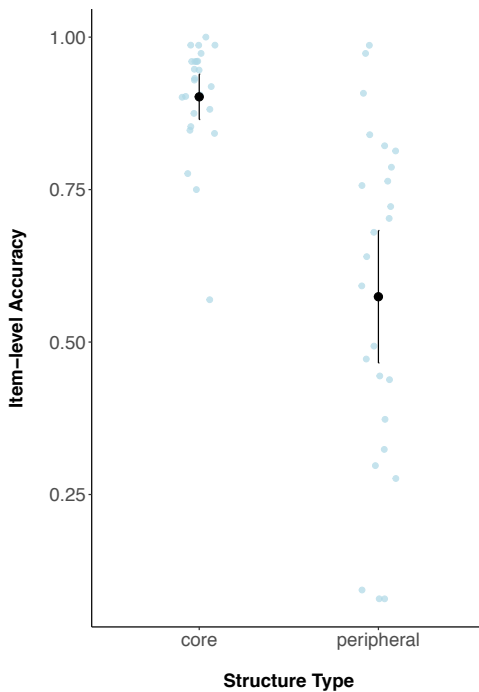
Response accuracy was coded as 1 or 0. For core and peripheral trials, “Ja” responses were coded 1 and “Nee” responses 0. For foil trials, the scheme was reversed (i.e., “Nee” = 1). To evaluate consistency within structures, we correlated the two examples of each core and peripheral structure. The strong positive correlation between the proportion of correct responses on example 1 and example 2 ( $\tau = .63$ ) indicates that difficulty *within* core and peripheral structures was largely consistent, allowing us to proceed with structure-level analysis. We calculated structure difficulty by averaging the proportion of correct responses obtained across the two examples. Table 1 presents a descriptive summary of item difficulty by type. The raw data plotted in Figure 2 illustrates the overlap in difficulty between many core and peripheral structures, despite the statistical difference in group means.

How well did linguists' intuitions predict accuracy on peripheral structures? There was a moderate negative correlation between the proportion of "peripheral" ratings a structure received from informants in the pre-test and its performance on the grammar test ( $\tau = -.20$ ). However, the correlation may be interpreted with caution, due to the narrow range in the proportion of peripheral ratings (0.57 – 1.00). The subjunctive (e.g., "Ware hij niet zo rijk geweest, hij had het nooit zo ver gebracht") was judged "peripheral" by all expert informants. This structure also caused the most difficulty in the test, with an average acceptance rate of 8% (irrespective of literacy group). Relatedly, there was a high rate of false positives (42%) for the ungrammatical foil sentence that resembled a subjunctive ("Ware hij niet zo laat, was alles goed"). Together, these findings suggest that many adult native speakers of Dutch have only partial knowledge of the subjunctive.

Notably, recognition of core-rated structures was not at ceiling. Structures that expert informants unanimously rated "Core (known by virtually all adult native Dutch speakers)" were rejected as incorrect on almost 10% of trials. Of the core-rated structures, comparatives using fronted *zo...als* (e.g., "Zo leuk als we gehoopt hadden is het helaas niet geworden") caused the most difficulty, with an average acceptance rate of 57%.

Item type	Mean accuracy (SD)	Range
Core	.90 (.09)	.57 – 1
Peripheral	.57 (.27)	.08 – .99
Foil	.87 (.1)	.65 – .99

**Table 1.** Item-level performance, summarised by type.



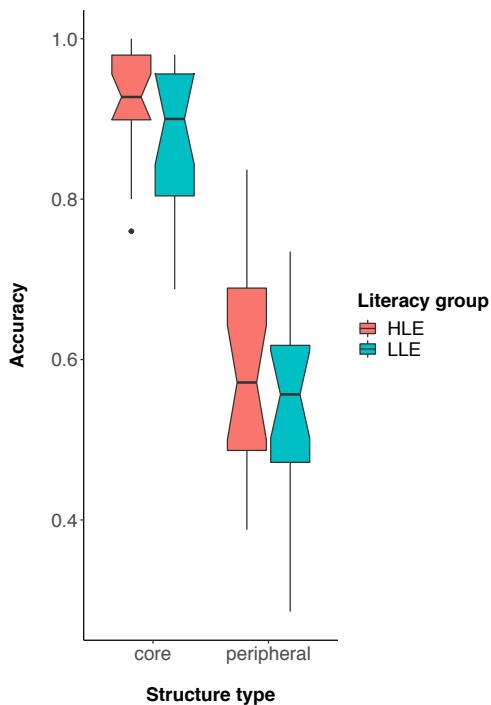
**Figure 2.** Mean-error-plot showing mean item-level accuracy for core and peripheral structures, plus raw item-level data. Error bars represent 95% confidence intervals.

### Participant-level analysis

We aggregated each participant's proportion of correct responses by item type. We also calculated individual d-prime ( $d'$ ) scores, a measure of overall test performance that controls for potential response bias (see Supplementary Materials for discussion). Table 2 summarises the results by literacy experience group. The groups show a similar pattern of performance across the three items types, e.g., they were least accurate on peripheral items. The HLE group was numerically more accurate than the LLE group in accepting both core and peripheral structures, and also showed a small advantage in mean  $d'$  scores. Group-level performance on individual structures is reported in the Supplementary Material. The number of structures that performed at ceiling (100% accuracy) differed between groups, with 14 in the HLE group (12 core) compared to only two structures at ceiling in the LLE group (both core). Interestingly, the correct rejection of ungrammatical foils appears unrelated to literacy experience. Figure 2 plots accuracy by literacy group on 'core' and 'peripheral' structures.

Group	Core	Peripheral	Foil	d'
HLE	.92 (.07)	.59 (.13)	.87 (.08)	1.82 (.30)
LLE	.88 (.09)	.54 (.11)	.87 (.11)	1.73 (.36)

**Table 2.** Summary of group-level performance. Mean proportion correct aggregated by literacy group and item type. D-prime scores (d') aggregated by group. Standard deviations given in brackets. HLE = High Literacy Experience; LLE = Low Literacy Experience.



**Figure 3.** Notched box-and-whisker plot showing the distribution of participant-level accuracy by literacy group, aggregated by structure type. HLE = High Literacy Experience; LLE = Low Literacy Experience. Each coloured box represents the interquartile range (IQR, i.e., 25<sup>th</sup> – 75<sup>th</sup> percentile); the ‘notches’ correspond to 95% confidence intervals for the median (marked in black). The ‘whiskers’ extend from minimum to maximum (respectively defined as  $Q1 - 1.5 \times IQR$  and  $Q3 + 1.5 \times IQR$ ). The single outlier is shown as a black point.

We used the *lme4* package in R (version 1.0.153; Bates et al., 2014) to fit a mixed logit model to the accuracy data. For simplicity, we analysed core and peripheral trials only (thus excluding data from all foil trials). The binomial

dependent variable was correct ('1') or incorrect ('0'). Structure type (Core/Peripheral) was a fixed factor in the model, with Core taken as the reference level. We included our index of literacy experience (Literacy PC1) as a continuous predictor, as well as its interaction with Structure Type.<sup>9</sup> Raven's Matrices and Backward Digit Span scores from Time 1 were added to the model as covariates, to account for the potential contribution of non-verbal IQ and verbal working memory respectively. All continuous predictors were mean centred. We included random intercepts for participant, sentence, and structure level (noun phrase/verb phrase/clause).

Predictor	Coefficient	SE	z value	95% CI
Intercept	3.07	0.38	7.99	2.21, 3.82
Literacy PC1	0.13	0.07	1.71	-0.02, 0.27
Type: Peripheral	-2.53	0.33	-7.78	-3.17, -1.89
Non-verbal IQ	0.03	0.02	1.58	-0.01, 0.07
Verbal WM	0.04	0.05	0.71	-0.06, 0.13
Literacy PC1 x Type: Peripheral	-0.03	0.05	-0.50	-0.13, 0.08

**Table 3.** Summary of fixed effects in the mixed logit model (N = 3680; Log likelihood = -1439.2). Intercept represents the log-odds of a correct response on a core trial for a participant with average literacy experience (Literacy PC1), non-verbal IQ, and verbal working memory (WM).

Table 3 presents the fixed effects in the mixed logit model of response accuracy (for the variance captured in the random part of the model see Table S4, Supplementary Material). The large positive coefficient for the intercept reflects the high average accuracy on core trials. There was only a very small effect of

<sup>9</sup> Model comparison revealed a better fit (log likelihood) with the continuous predictor Literacy PC1 as opposed to the categorical predictor literacy experience group.

literacy experience on the log odds of responding correctly on core trials (the positive coefficient for Literacy PC1). As predicted, there was a robust effect of structure type on accuracy, such that peripheral structures were far less likely than core structures to be recognised as grammatical. There was a weak positive relationship between accuracy and non-verbal IQ, although this was not statistically robust, and there appeared to be no association with verbal working memory. Finally, we did not find evidence for an interaction between literacy experience and structure type, indicating that the small advantage associated with increased literacy experience did not differ between core and peripheral structures.

## Discussion

In order to investigate the empirical basis for ‘core’ and ‘peripheral’ syntactic structures in the Dutch language, we collected grammaticality judgments from adult native Dutch speakers with varying levels of literacy experience. Half of the target structures had previously been classified by a panel of linguist informants as “Core (known by virtually all adult native Dutch speakers)”, and half as “Peripheral (unknown to many native speakers)”.

### *‘Core’ structures*

Consistent with the intuitions of linguist informants, there was a large discrepancy in overall performance on core and peripheral structures. On average, core structures were over 30% more likely than peripheral structures to be accepted as correct Dutch. For example, all participants demonstrated knowledge of the *aan het* continuous construction (e.g., “De schilder was verf aan het mengen”). Unsurprisingly, our results broadly support the notion that the majority of adult native speakers share at least some syntactic knowledge (i.e., ‘core’ grammar). The limited convergence we observed amongst participants on core-rated structures, however, does not fit easily with the categorical definition of ‘core’ grammar espoused in generative linguistics (e.g., Broekhuis & Keizer, 2012, Chomsky, 1981). Several structures unanimously classified as ‘core’ by linguists performed well below ceiling in our educationally diverse sample (e.g.,

clause-level ellipsis; “Theo is vaak weg, maar ik bijna nooit”). This echoes previous findings of substantial individual variation in the comprehension of supposedly ‘core’ constructions amongst native English speakers (e.g., universal quantifiers; Street & Dąbrowska, 2010; Dąbrowska, 2018).

### *‘Peripheral’ structures*

Interestingly, there was not much unanimity in the pre-test classification of peripheral structures by our expert informants (linguists), perhaps because the delineation of the ‘periphery’ is not straightforward for Dutch (Los, 2016). The shortlisted structures also varied considerably in their performance on the test, correlating weakly with the proportion of peripheral ratings received in the pre-test. Somewhat contrary to linguists’ intuitions, eight peripheral structures obtained an average acceptance rate of over 75%. In particular, the continuous construction with past and present participles (e.g., “De deur op slot gedaan hebbende, verliet hij het huis”) performed unexpectedly well, given the consensus among informants that it would be unknown to many native speakers. In contrast, as many as half of the peripheral structures scored below chance level in our sample, highlighting the disparity between descriptive grammars (“magnasyntax”) and the knowledge that most native speakers actually acquire (Miller & Weinert, 1998). The low prevalence of these structures in the general population might be explained by their restricted usage (e.g., highly formal registers), combined in many cases with irregularity (Broekhuis, 2016). For example, the comparative construction within an exclamative (as in “Ze moeten toch altijd doen als wisten ze alles!”), which was rejected in 92% of trials, deviates from canonical subordinate clause word order. The wide range in accuracy on peripheral-rated structures provides further support for a continuous distribution of prevalence, and casts doubt on the viability of a categorical distinction between ‘core’ and ‘peripheral’ grammar.

### *Measuring syntactic knowledge*

The present data on adult native Dutch speakers’ receptive syntactic knowledge complements Hulstijn’s description of syntactic *production* in a similar population (2017). That pilot study was intended as a first step towards



establishing the productive inventory of syntactic patterns shared by (virtually) all adult native Dutch speakers (with the broader aim of defining what a native speaker minimally constitutes in linguistic terms). When comparing the present findings to Hulstijn (2017), it is important to bear in mind that differing task demands can give rise to asymmetries in performance across comprehension and production (McCauley & Christiansen, 2013). Because accurate grammaticality judgment can be achieved with only a “shallow parse” of the sentence, supported by semantic knowledge, language users may accept structures as grammatical without having the mastery needed to use them in production. For example, pre-nominal participle phrases were accepted with 85% accuracy on our test but were almost entirely absent from the 80,000-word spoken corpus described by Hulstijn (2017). On the other hand, fronted conjunction-less clauses expressing contrast were rejected as ungrammatical on almost 50% of trials in our test *and* did not feature at all in the corpus, suggesting that this property of Dutch may be truly ‘peripheral’. Similarly, several ‘core’ structures that were used by the majority of speakers in Hulstijn (2017) were also amongst the best performing in our data (e.g., relative clauses and fronted conditional clauses with *als*, both of which obtained at least 90% accuracy).

### *Influence of literacy experience*

We predicted that participants with more literacy experience would perform better overall in recognising the structures as correct Dutch, in line with the usage-based assumption that syntactic knowledge is shaped by the input (e.g., Bybee, 2006), which should be of a higher quality and quantity for highly experienced literates. Interestingly, we observed only a small numerical difference in accuracy (approximately 5%) in favour of the HLE group. Modelling analysis that accounted for differences in general cognitive abilities revealed the independent contribution of literacy experience to be statistically marginal. In addition, there was no evidence for an interaction between literacy experience and structure type, indicating that there was no additional benefit of literacy experience for recognising peripheral structures. This is surprising, since given the characteristic low frequency and restricted usage of these structures, we had predicted that highly experienced literates would be the most likely to

have encountered them before. Further, specific prior exposure was expected to benefit peripheral structures in particular because of their complexity and/or irregularity (MacDonald & Christiansen, 2002).

What then may explain the absence of a robust literacy effect in the present study? One may argue that the sample size ( $N=38$ ) was simply too small. This alternative explanation is unlikely to account for the absence of a (literacy) effect found here, because the same participants (pre-selected for their literacy differences from a pool of 161 individuals) had also participated in another study on the same day, which observed robust effects of literacy on syntactic processing (Favier et al., under review). While it is conceivable that a future study with a very large sample size may find a statistically significant difference, the effect size would likely be small. We believe that a more probable explanation for the similar performance of HLE and LLE groups in the present study is that native speakers' syntactic knowledge as assessed by grammaticality judgments *over a wide range of structures* (50 structures in the present study) is on the whole rather good. Many syntactically legal structures in Dutch may simply be 'too peripheral' for the large majority of native speakers, occurring so infrequently that most participants had never (or very rarely) encountered them before, regardless of literacy experience. Corpus analyses of contemporary Dutch texts could be used to evaluate the empirical basis for this.

Although there are certainly some syntactic structures that people with low literacy experience are less familiar with (e.g., prescriptive usage of *als/dan*, *mij/ik*, *hun/ze*, *die/dat*; Favier & Huettig, under review), the present study suggests that these are comparatively few. The notion that literacy-related differences only emerge for some structures is supported by our item-level data. Although the level of accuracy across groups was generally high, the item-level data reveal that the HLE group was six times more likely than the LLE group to perform at ceiling on *some* core structures. If we take 100% acceptance as the criterion for inclusion, the body of syntactic knowledge shared by the HLE participants was relatively large (comprising about half of the core structures tested). In contrast, LLE participants unanimously converged on only two core structures (given these strict inclusion criteria).

### *Conclusions*

We observed systematic differences in the grammaticality judgments of adult native Dutch speakers that broadly corresponded to Dutch linguists' intuitions regarding 'core' and 'peripheral' syntactic knowledge. Importantly however, within these categories, there was substantial variability in participants' judgments, which suggests that a categorical distinction between a 'core' grammar and a 'periphery' may not be tenable. Contrary to our expectation, individual differences in literacy experience only explained a small amount of the variance in grammatical judgements of 'core' and 'peripheral' syntactic structures. Thus, overall, the present findings appear to fit best with usage-based views that there is a continuum of syntactic knowledge and that more frequent syntactic structures are mastered better (and by more people) than infrequent ones.

## 4. Literacy enhances syntactic prediction in spoken language processing<sup>10</sup>

Language comprehenders can use syntactic cues to generate predictions online about upcoming language. Previous research with reading-impaired adults and healthy, low-proficiency adult and child learners suggests that reading skills are related to prediction in spoken language comprehension. Here we investigated whether differences in literacy are also related to predictive spoken language processing in non-reading impaired proficient adult readers with varying levels of literacy experience. Using the visual world paradigm enabled us to measure prediction based on syntactic cues in the unfolding spoken sentence, prior to the (predicted) target word. Literacy experience was found to predict target anticipation, independently of general cognitive abilities. These findings suggest that a) experience with *written* language enhances syntactic prediction of *spoken* language in normal adult language users, and b) processing skills can be transferred to related tasks (from reading to listening) if the domains involve similar processes (e.g., predictive dependencies) and representations (e.g., syntactic).

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<sup>10</sup> Adapted from Favier, S., Meyer, A. S., & Huettig, F. (under review). *Literacy enhances syntactic prediction in spoken language processing*.

## Introduction

Prediction has become the dominant theoretical framework for understanding the functioning of the mind and brain. As well as playing an integral role in perception, action, and learning (Clark, 2013; Friston, 2005), the pre-activation of predictable information is argued to reduce processing load and increase efficiency across multiple cognitive systems (e.g., Bar, 2003). Notably, psycholinguistic research increasingly emphasises the importance of anticipatory mechanisms in language processing (e.g., Altmann & Mirkovic, 2009; Dell & Chang, 2014; Federmeier, 2007; Ferreira & Chantavarin, 2018; Gibson et al., 2013; Hale, 2001; Hickok, 2012; Huettig 2015; Kuperberg & Jaeger, 2016; Levy, 2008; Norris et al., 2016; Pickering & Gambi, 2018; Pickering & Garrod, 2013; Van Petten & Luka, 2012). However, most studies thus far have ignored the question of individual variation in predictive language processing (but see Federmeier et al., 2010; Hintz et al., 2017; Huettig & Janse, 2016; Kukona et al., 2016; Rommers et al., 2015).

The determinants (and extent) of individual differences in anticipatory language processing, however, may reveal important insights about the role and mechanisms of prediction in language and cognition more generally. In recent years, mounting evidence has suggested that individual variation in reading skills may be an important factor even in anticipatory *spoken* language processing. Studies with reading-impaired adults (Huettig & Brouwer, 2015), healthy low-proficiency adults (Mishra et al., 2012), and child learners (Mani & Huettig, 2014) provide converging evidence that reading skills have a bearing on prediction in spoken language. But are these effects the hallmark of an impaired/developing system or are they a general feature of proficiency transfer between two related domains (reading and speech prediction)? This is an important question because it promises to illuminate the relationship between predictive processing and proficiency within a given domain, as well as the transfer of training/experience between related domains.

Here we aimed to address these issues by investigating prediction in language processing (defined as the pre-activation of linguistic representations before incoming bottom-up input has had a chance to activate them, Huettig, 2015) in

non-reading impaired healthy adults with varying levels of literacy experience. One previous study provides some tentative evidence. Ng et al. (2018) asked a community sample of adults with varying literacy levels to listen to spoken sentences. Proficient readers showed reduced ERP negativity for strongly predictable target words over anterior channels, in a time window from 170 to 300ms after target word onset, but the same ERP response was not found in less-skilled readers. Neural correlates of prediction measured on the target word (and not before), however, can be explained by a number of other (non-predictive) accounts, such as differences in the integration of non-predicted representations (for further discussion see Baggio & Hagoort, 2011; Huetig, 2015; Mantegna et al., 2019; Nieuwland et al., 2018, 2020).

In the present study, we chose to investigate syntactic prediction because syntactic proficiency is expected to increase with literacy experience. Readers are exposed to a rich syntactic environment that is considerably more complex and diverse than typical conversational speech. Written narratives contain 60% more instances of subordination than speech (Kroll, 1977) and relatively infrequent structures like passives, object relative clauses, and participial phrases are predominantly attested in written corpora (e.g., Roland et al., 2007). The impact of written language exposure on syntactic proficiency has been demonstrated both for comprehension (Street and Dąbrowska, 2010; Langlois & Arnold, 2020) and production (Montag & MacDonald, 2015), in children and adults (e.g., Crain-Thoreson & Dale, 1992; Dąbrowska, 2018). Several have investigated syntactic prediction (e.g., Arai & Keller, 2013; Chen et al., 2005; Kamide et al., 2003; Staub & Clifton, 2006) but (to the best of our knowledge) none assessed the influence of reading experience on syntactic anticipation in healthy literate adults.

Here we used the visual world paradigm to measure eye gaze as a straightforward marker of prediction. We asked Dutch adults with high and low literacy experience to listen to passive sentences such as (1) in conjunction with visual displays such as Figure 1.

- (1) Het raam wordt inderdaad gebroken door een stier.  
*The window is indeed broken by a bull.*

The auxiliary “wordt” is an early but unreliable indicator of passive voice, since it could also be parsed as an intransitive main verb (e.g., “Hij wordt rijk”, *He gets rich*). Only at the participle (“gebroken”) can the grammatical function of “wordt” be disambiguated, and the preverbal argument (“Het raam”) be assigned the role of patient. In other words, there is sufficient information at the participle to parse the unfolding sentence as passive, and to *predict* that a prepositional complement specifying the agent may follow. The preposition “door”, *by*, provides the final and unequivocal cue to expect an agent.

## Method

### *Participants*

Thirty-eight native Dutch speakers volunteered to participate in the experiment (mean age = 25.2; 25 females). We recruited from a pool of 161 participants with varying degrees of literacy experience who had completed a battery of individual difference measures as part of a different study (Favier & Huettig, under review). We performed a pre-registered principal components analysis on six literacy measures (Peabody receptive vocabulary, author recognition, reading habits, spelling, word and pseudoword reading) to derive an underlying construct that explained the maximal amount of variance in the literacy data (Literacy PC1 in Table 1)<sup>11</sup>. For the current study, we tested all participants in the top and bottom quartiles for Literacy PC1 who responded to our invitation for the eye-tracking experiment. The resulting sample size (N=38) is similar to previous visual world studies that observed syntactic prediction effects with 30-40 participants (Kamide et al., 2003; Arai & Keller, 2013). One participant was excluded because the eye tracker failed to calibrate to their eyes. There is a pronounced group difference in literacy experience, based on Literacy PC1 ( $t = 8.70, p < 0.001$ ) and ART 2 scores ( $t = 4.01, p < 0.001$ ). The small difference in non-verbal IQ (Raven's) scores between high and low literacy experience groups ( $t = 2.10, p = 0.04$ ) was

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<sup>11</sup> A more detailed description of the tests used, the principal components analysis and other further analyses, as well as the data are available in the supplementary materials on [https://osf.io/pds4w/?view\\_only=cc7a95d3b0414b2e8e86a86eda0a5d10](https://osf.io/pds4w/?view_only=cc7a95d3b0414b2e8e86a86eda0a5d10)

expected and is in line with previous research (e.g., Hervais-Adelman et al., 2019, Olivers et al., 2014; Skeide et al., 2017).

Literacy experience	n	Age	Literacy PC1 score	ART 1	ART 2	Non-verbal IQ	Verbal WM
<b>High</b>	20	26.10 (4.41)	1.50 (.89)	13.85 (11.57)	16.25 (12.30)	22.30 (6.11)	7.30 (2.20)
<b>Low</b>	18	24.16 (1.89)	-1.69 (1.30)	4.06 (3.30)	4.67 (3.72)	18.28 (5.72)	8.39 (2.68)

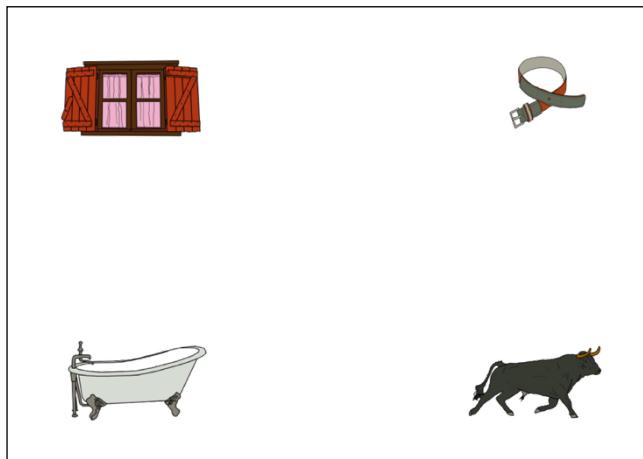
**Table 1.** Descriptive summary of high and low literacy experience groups. Group means are based on raw scores for individual difference measures (except Literacy PC1, a derived score). Standard deviations are shown in brackets. PC1 = First Principal Component; ART 1 and ART 2 = Author Recognition Test at Time 1 and Time 2 respectively; WM = Working Memory. Literacy PC1 incorporates scores on the Dutch version of the Author Recognition Test (ART 1; Brysbaert et al., 2013; Stanovich & West, 1989). The ART was re-administered (ART 2) to assess any possible change in literacy experience that could have occurred in the intervening period. Non-verbal IQ and verbal working memory were assessed using Raven’s Progressive Matrices and the Backward Digit Span task respectively.

### *Materials*

24 Dutch passive sentences were constructed by combining a set of 12 transitive verbs with 24 inanimate patients (objects) and 24 animate agents (animals), such that each verb was presented twice. As our aim was to assess syntactic prediction, we avoided object-animal pairings with salient semantic associations (e.g., shoe-dog), in favour of less typical combinations (e.g., paintbrush-dog). All experimental sentences used the present-tense passive frame shown in (1), i.e., Patient + Present Passive Auxiliary + Adverb + Participle + Preposition + Agent. The semantically light adverb “inderdaad”, *indeed*, served as ‘padding’, increasing the power to detect potential syntactic prediction effects. Each experimental sentence was paired with a visual display, comprising four colour



pictures from the MultiPic database (Duñabeitia et al., 2017): an inanimate entity (the patient), an animate entity (the agent, henceforth the target), and two semantically unrelated distractors (Figure 1).

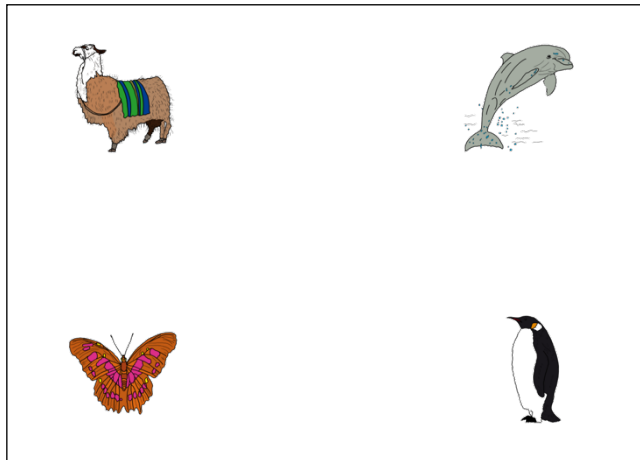


**Figure 1.** Example visual display for the (passive) spoken sentence “Het raam wordt inderdaad gebroken door een stier” *The window is indeed broken by a bull*, in which “stier” is the target picture. Distractors were always inanimate objects, and none were plausible agents of the events described. There were no statistical differences in mean frequency of picture labels (Table 2) in the four sets of pictures ( $F = 0.09$ ;  $p = 0.97$ ). Picture positions were pseudo-randomised such that patient and target entities appeared equally often in all four positions on the visual display. There was no repetition of pictures in the experiment.

Picture set	Patient	Target	Distractor 1	Distractor 2
Log10 frequency: Mean (SD)	2.64 (.86)	2.57 (.60)	2.60 (.68)	2.54 (.82)

**Table 2.** Descriptive summary of Log10 word frequency values for experimental picture labels, grouped by set (SUBTLEX-NL; Keuleers, Brysbaert, & New, 2010).

In addition, 60 filler items using intransitive verbs (e.g., “De caravan staat inderdaad best ver weg van de molen” *The caravan is indeed quite far away from the windmill*) were constructed. A subset of 14 fillers was used as reference items, to provide a by-participant experimental baseline for lexical processing speed. We constructed the reference items such that the sentence-final entity (the target) could not easily be predicted from either the sentence context or the pictures in the visual display (Figure 2). Auditory stimuli were recorded in a soundproofed booth by a female native Dutch speaker, using a Sennheiser ME64 microphone. The recording was sampled at 44kHz (mono) with 16bit sampling resolution.



**Figure 2.** Example filler visual display for the spoken sentence “De vlinder lijkt inderdaad veel kleiner dan een dolfijn” *The butterfly indeed seems much smaller than a dolphin*, in which the unpredictable target word is “dolfijn”.

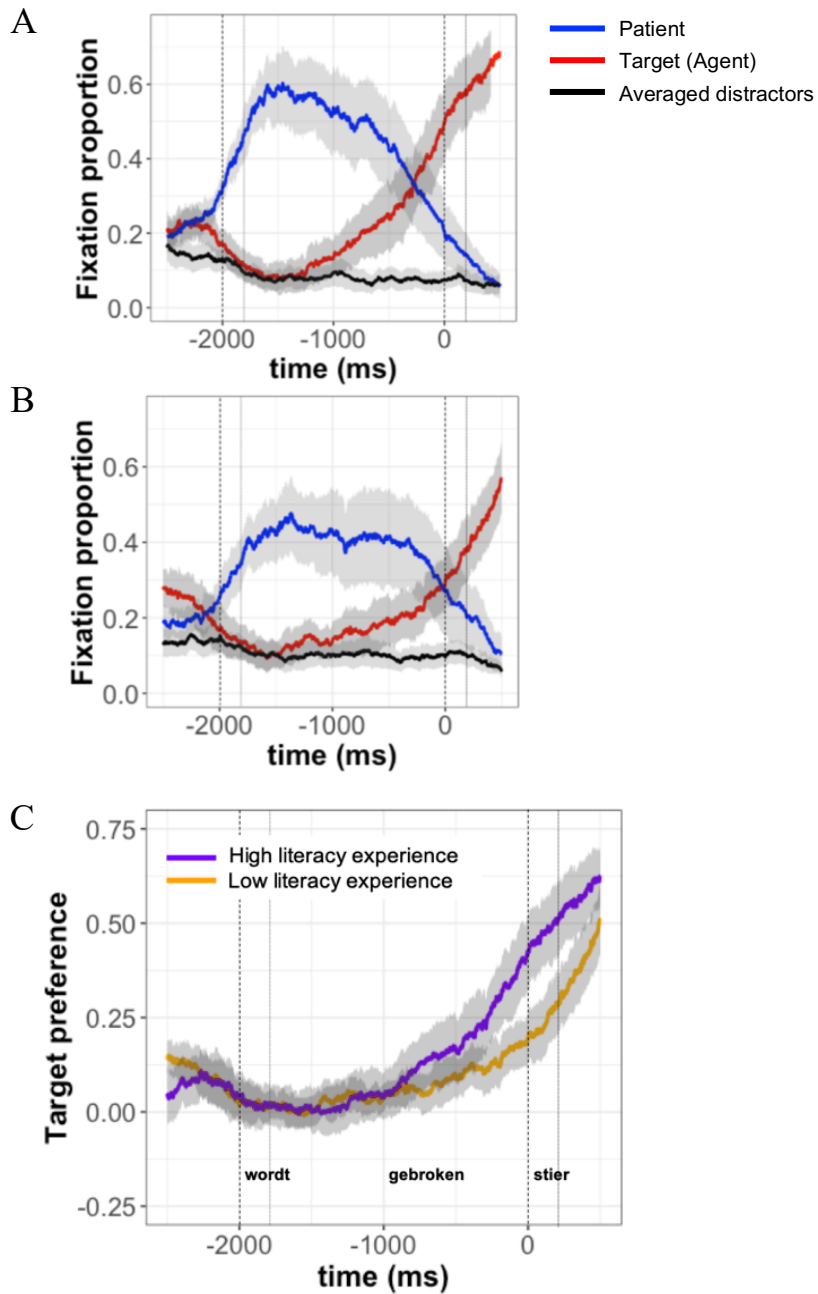
### *Procedure*

Participants were tested individually in a soundproofed experiment booth. An SR Research EyeLink 1000 tower-mounted eye tracker was used to record eye movements. Participants were instructed to avoid moving their eyes away from the screen and to listen carefully to the sentences presented via headphones (a well-established protocol, particularly in experiments on prediction in language processing; see Huettig, et al., 2011, for further discussion).

Each trial began with a one-second central fixation, followed by a visual display. There was a two-second preview of the pictures before the onset of the cue (“wordt”) in the speech signal. The pictures remained on the screen until 2500ms after the onset of the target word. The mean duration of the critical window between cue and target onset was 2005ms in passive trials and 2162ms in reference trials (here, the cue was defined as the verb, e.g., “lijkt” *seems*). There were 84 trials in total, of which 29% were passive and 71% were fillers. The order of trials was automatically pseudo-randomised for each participant (with a maximum of two consecutive passive trials). The experiment took approximately 20 minutes, including calibration.

## Results

Eyelink DataViewer was used to code fixations, saccades and blinks. Data from four out of 888 experimental trials were missing due to track loss. Fixation locations were coded automatically with respect to pre-defined regions of the visual display: patient, target, distractor 1, distractor 2, and background (i.e., none of the pictures). In the high literacy experience (henceforth HLE) group, 2% of fixations on experimental trials were coded as background. One participant in the low literacy experience (henceforth LLE) group was excluded due to 79% background fixations. For the remaining LLE group (n=17) the rate of background fixations was 2%. Figure 3 shows the averaged fixation proportions to the target, patient, and averaged distractors on passive trials for HLE (Panel A) and LLE groups (Panel B), and a difference score, i.e., the time course of target preference for each group (Panel C). Visual inspection of the plots suggests that the HLE group anticipated the target earlier than the LLE group (see Table 3 for group means).



**Figure 3.** The time window of interest extended from the acoustic onset of “wordt” to the onset of the target word (time zero), both adjusted by 200ms to

account for the time taken to program and launch a language-mediated saccadic eye-movement (Saslow, 1967). Panel A plots fixation proportions to patient (blue), target (red) and averaged distractor entities (black) for the HLE group (n=19). Panel B plots fixation proportions to the same entities for the LLE group (n=18). Panel C plots the difference between target and distractor fixations (i.e., target preference) by group, calculated by subtracting the proportion of averaged distractor fixations from the proportion of target fixations at each time step. Patient fixations were not included in this calculation. A target preference of zero means that the target and averaged distractors were fixated equally often, while values greater than zero reflect relatively more fixations to the target. The grey shaded areas represent by-participant 95% confidence intervals, computed at each 1ms sampling step (Masson & Loftus, 2003). Vertical dashed lines indicate the acoustic onsets of “wordt” (mean = -2005) and the target word (time zero). Vertical dotted lines represent a +200ms adjustment to onset times, reflecting the typical latency of language-mediated eye movements. In Panel C, the approximate onset of the participle in the speech signal (mean = -1003ms) is indicated by “gebroken”. HLE = High Literacy Experience group; LLE = Low Literacy Experience group.

Group	Target	Averaged distractors	Background
HLE	.23 (.22)	.08 (.12)	.02 (.08)
LLE	.19 (.21)	.11 (.14)	.02 (.07)

**Table 3.** Mean fixation proportions (passive trials) to the target, averaged distractors, and background for the high (HLE) and low (LLE) literacy experience groups during the critical time window (200ms after “wordt” onset until 200ms after target onset) on passive trials. Standard deviations are provided in brackets.

The 14 non-predictive reference items were analysed to provide a baseline for lexical processing speed. This was indexed as the log odds of fixating the target entity in the first 500ms after target word onset, averaged across reference items. The mean rate of target fixations during this window was 35% (SD = 11%) for the HLE group and 30% (SD = 12%) for the LLE group, indicating a relatively small group difference. The empirical logit function (Barr, 2008) was used to transform individuals' average target gaze durations to log odds, providing a participant-level index of lexical processing speed.

### *Inferential statistics*

To analyse the amount of variance in anticipatory eye movements that could be explained by literacy experience, we fit a linear mixed-effects model (Table 4) to the eye-tracking data from passive trials, using the *lme4* package in R version 1.2.1335 (Bates et al., 2014; R Core Team, 2019). The dependent variable was calculated for the 'predictive period' between the acoustic onset of "wordt" (+200ms) and the onset of the target noun (+200ms). We first aggregated gaze durations by participant, item, and display region, then transformed the durations to log odds using the empirical logit function. Finally, the averaged log odds of looks to the two distractors was subtracted from the log odds of looks to the target. Our dependent variable was the resulting difference score, which indicates the strength of target preference. Literacy experience group (Low/High) was a fixed factor in the model, with Low treated as the reference level. The model contained lexical processing speed as a continuous predictor (calculated as described above and mean centred), and its interaction with literacy experience group, to account for the possibility that efficiency of word-object mapping mediated any literacy effect. To evaluate the contribution of the Literacy PC1 that was independent of general cognitive abilities, we also included non-verbal IQ and verbal working memory scores (mean centred). Individual scores on the measures were mean-centred and entered into the model as continuous predictors. Finally, we added random intercepts for participants and items. Statistically confirming the divergent trajectories shown in Figure 3 (Panel C), target preference was stronger in the HLE than LLE group (a conclusion also supported by growth curve analysis; see Appendix). There was no robust evidence for an

interaction between literacy experience and lexical processing speed, nor for a main effect of lexical processing speed on target preference. Finally, the results indicate that non-verbal IQ and verbal working memory contributed little to anticipatory eye movements.

Predictor	Coefficient	SE	<i>t</i> value	95% CI
Intercept	1.24	0.38	3.25	0.49, 1.99
Literacy experience: High	1.16	0.56	2.06	0.06, 2.26
Lexical processing speed	0.13	0.52	0.24	-0.89, 1.14
Non-verbal IQ	0.02	0.05	0.37	-0.07, 0.11
Verbal working memory	0.07	0.10	0.69	-0.13, 0.27
Literacy experience: High x Lexical processing speed	0.53	0.90	0.59	-1.22, 2.29

**Table 4.** Summary of fixed effects in liner mixed-effects model (N = 837). The intercept represents target preference (log odds of fixating target minus log odds of fixating distractors) for a participant in the LLE group with average lexical processing speed, non-verbal IQ, and verbal working memory. SE = Standard Error; CI = Confidence Interval. The positive intercept reflects the LLE group's relatively higher odds of fixating the target versus the distractors (i.e., target preference) during the critical time window.

## Discussion

The present results corroborate existing evidence that language comprehenders can use syntactic cues to generate predictions online about upcoming language (e.g., Arai & Keller, 2013; Chen et al., 2005; Kamide et al., 2003; Staub & Clifton, 2006). More importantly, the current study presents the first clear

experimental evidence from non-reading impaired adults that syntactic prediction in spoken language comprehension is related to adults' literacy experience. The eye-tracking method used here enabled us to measure syntactic prediction in speech processing unequivocally (i.e., before participants heard the anticipated target). Literacy experience emerged as the strongest predictor of target (i.e., agent) preference, independent of general cognitive abilities. The main effect of literacy experience on anticipatory eye-movements in our study echoes previous observations of reading-related differences in spoken language prediction based on other types of information (e.g., semantic representations, Mani & Huettig, 2014; grammatical gender, Huettig & Brouwer, 2015) that has previously been reported in the literature.

There are a number of alternative explanations for the present literacy-related syntactic prediction effect that can be rejected. First, one may argue that the group difference in anticipatory eye movements simply reflect slower word-object mapping in less experienced literates, since language experience has previously been linked to the efficiency of language-mediated looking (e.g., James, 2014; Mishra et al., 2012). We designed a baseline measure of lexical processing speed to address this potential confound and observed no evidence for an interaction between literacy experience and lexical processing speed, nor for a main effect of lexical processing speed on target preference. Second, one may suggest that differences in prediction simply reflect general ability (g-factor) differences that are measured by intelligence tests rather than differences in literacy experience. We can also reject this alternative explanation. Previous research has found that increased literacy and education results in small increases in Raven's scores (e.g., Hervais-Adelman et al., 2019, Olivers et al., 2014; Skeide et al., 2017). Moreover, the minimal contribution of non-verbal IQ in our results is consistent with previous findings that Raven's performance explains very little unique variance in language-mediated prediction (Hintz et al., 2017; Huettig & Janse, 2016; Rommers et al., 2015).

How does literacy experience influence syntactic prediction in spoken language processing? It is useful to distinguish between primary and secondary influences of reading experience, both of which affect the core processes and representations that are common to written *and* spoken language (Huettig &



Pickering, 2019). Secondary influences arise as a consequence of exposure to ‘book language’, which is syntactically more elaborate (with higher demands on verbal memory) and contains more extensive and sophisticated vocabulary than conversational speech. These influences can thus also be attained by listening to auditory ‘book-like’ material. For example, it has been shown that the amount of shared book reading with parents at two years of age predicts children’s comprehension of syntactically complex sentences at two and a half years (Crain-Thoresen et al., 2001). Moreover, for children and adults alike, literacy results in both increased vocabulary knowledge (Cain & Oakhill, 2011; Cunningham & Stanovich, 1991) and verbal working memory (Démoulin & Kolinsky, 2016; Smalle et al., 2019).

Primary influences are those that are more directly linked to the physical act of reading (e.g., efficient decoding of written language; increased exposure to the extreme form-invariance of printed word forms; parallel processing of multiple letters/words in proficient readers; see Huettig & Pickering, 2019, for further discussion). The present results cannot conclusively distinguish between primary and secondary influences of reading on the spoken language prediction we observed, since our (statistically-determined) index of literacy experience included both secondary (receptive vocabulary, author recognition) and primary (word and pseudoword reading, spelling) components. It is noteworthy that verbal working memory contributed very little to the observed anticipatory eye movements (cf. Huettig & Janse, 2016). To further assess causality and the individual contributions of primary and secondary influences of reading on (syntactic) prediction, a large-scale study with a longitudinal design would be useful.

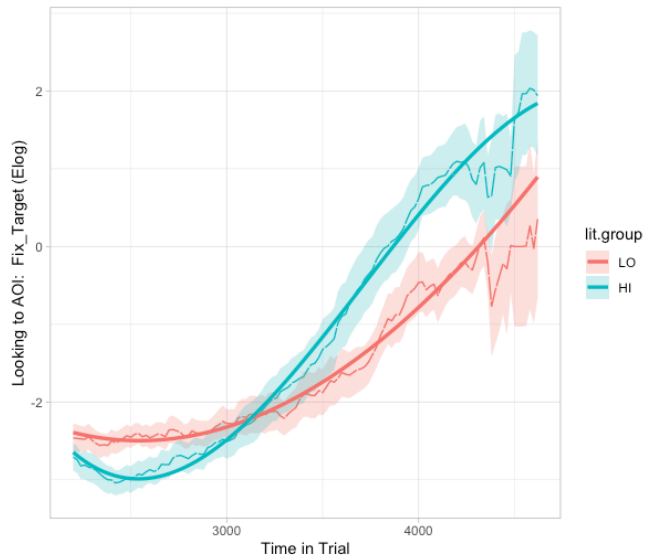
To sum up, the present study showed an effect of literacy experience on the anticipation of upcoming language, which strongly suggests that proficiency is important for predictive processing. Strikingly, experience with *written* language was found to enhance syntactic prediction of *spoken* language in normal adult language users. Theories of prediction in language processing, and in cognitive science more generally, must be adapted to account more explicitly for the observation that prediction is contingent on experience, not only with respect to the task at hand (e.g., spoken language processing), but also related ones (e.g.,

reading). We posit that processing skills transfer to related tasks if the domains share similar processes (e.g., predictive dependencies) and representations (e.g. syntactic).

## **Appendix.** Supplementary growth curve analysis

We used quasi-logistic growth curve analysis (Mirman, 2014) to analyse the time course of anticipatory target fixations from 200ms after “wordt” onset to 200ms after the onset of the agent noun. First, we summarised the data into 20ms time bins and calculated target fixation proportions for each bin. 91 of 888 experimental trials were deleted prior to analysis due to track loss above the 25% threshold. The average number of trials contributed by each participant was 22.14 (SD = 2.71). Growth curve analysis was carried out using the *lme4* package in R version 1.2.1335. A third-order (cubic) orthogonal polynomial captured the overall time course of agent fixations in this window. We included a fixed effect of literacy experience (low vs. high) on all time terms, as well as by-participant random intercepts and slopes for each polynomial. The categorical predictor (literacy experience) was sum-coded and centred before being entered into the model.

We used stepwise model comparison to assess the statistical significance of parameter estimates. There was a positive effect of literacy experience on the intercept (estimate = .41, SE = .28), indicating that the overall odds of fixating the target entity during the critical window was higher for the HLE group. There was a significant positive effect of literacy experience on the linear term (estimate = 7.12, SE = 2.80), reflecting a steeper slope (i.e., faster increase in target fixations over time) in the HLE group compared to the LLE group. We did not find evidence for an effect of literacy experience on either the quadratic or cubic terms, suggesting that the curvature of the slopes did not differ significantly between the groups.



**Figure A1.** Predictions of the best fitting growth curve model, plotted on top the actual data. Model code: *lmer(Elog ~ lit.groupC\*(ot1 + ot2 + ot3) + (1 + ot1 + ot2 + ot3 | participant), data = response\_time, REML = FALSE)*

## **5. Investigating verb transitivity as a cue to prediction during spoken sentence comprehension in Dutch**

Evidence from eye-tracking studies shows that comprehenders can predict upcoming syntactic structure based on a variety of linguistic cues. These cues shed light on the type of information that influences the early stages of sentence parsing. Notably, the prediction of post-verbal arguments based on verb transitivity, as demonstrated by Arai and Keller (2013) in English, suggests that fine-grained, lexically specific information can be accessed immediately by the sentence parser. The Dutch language shares with English the syntactic constraint that transitive verbs require a direct object. We conducted a visual world eye-tracking experiment, similar in design to Arai and Keller (2013, Experiment 1), to examine verb transitivity as a cue to prediction in Dutch. Participants were adult native speakers with varying levels of literacy experience, based on previous research suggesting that spoken language prediction is enhanced by literacy. We observed a small numerical increase in listeners' anticipatory looks to the direct object entity on hearing a transitive verb relative to an intransitive verb. However, the effect of verb transitivity was not statistically robust. We were thus unable to draw conclusions about the contribution of literacy experience to verb-mediated syntactic prediction.

## Introduction

An important question for sentence processing research concerns the type of information comprehenders use to construct an initial syntactic analysis. Studies of predictive sentence processing, and syntactic prediction in particular, can provide valuable insights into the parsing process. Within the vast prediction literature, a small body of research demonstrates that listeners generate expectations about upcoming syntactic structure based on a variety of linguistic cues. For example, case marking in German and Japanese has been found to influence listeners' interpretation of the unfolding sentence as active or passive, as indexed by anticipatory eye-movements to compatible arguments in the visual scene (Kamide et al., 2003a, 2003b). In these studies, predictive parsing did not rely on lexically specific information, as the morphosyntactic cues were independent of the lexical items used. A more recent investigation of syntactic prediction conducted by Arai and Keller (2013) directly examined the influence of fine-grained, lexically specific information in the early stages of sentence parsing in English. They found that the prediction of upcoming syntactic structure was facilitated both by verb-specific subcategorisation information (Experiment 1) and verbs' frequency of occurrence in a particular form (Experiment 2). Importantly, these effects were measured at the site of the verb itself rather than further downstream, as in other studies of verb-specific effects on syntactic processing, which had hitherto produced mixed results (Pickering et al., 2000; Pickering & Traxler, 2003; cf. Staub & Clifton, 2006).

We chose to focus on the syntactic prediction effect reported by Arai and Keller (Experiment 1, 2013) whereby verb transitivity modulated anticipatory eye movements to an upcoming direct object. We were interested in whether this finding could be extended to Dutch, which shares with English the phenomenon of transitivity and the syntactic constraint that transitive verbs require a direct object. In the original visual world eye-tracking experiment, native English speakers heard sentences that contrasted exclusively transitive verbs with verbs that almost always occur in intransitive constructions. Arai and Keller hypothesised that transitive verbs (e.g., “upset” in 1a) would trigger anticipatory looks to the only plausible direct object entity (e.g., the prince) in a visual scene

that also contained the subject entity (e.g., the witch) and an inanimate distractor object (e.g., a pair of shoes). Importantly, sentence 1b or 1c presented in conjunction with the same scene should be less likely to elicit verb-mediated anticipatory eye-movements, because “glared” does not license a direct object. This is not to suggest that “glared” contains no relevant predictive information: the fact that it licenses an optional prepositional object (as per 1b) could also trigger anticipatory looks to the prince. However, the non-optional syntactic constraint introduced by “upset” is expected to provide a stronger predictive cue.

- 1a. Apparently, the witch upset the prince.
- 1b. Apparently, the witch glared at the prince.
- 1c. Apparently, the witch glared, and the prince threw the shoes.

Both saccade probability and gaze logit analysis revealed that listeners were indeed more likely to make anticipatory eye movements to the target (i.e., the prince) on hearing a transitive verb versus an intransitive verb. The probability of at least one saccade being launched towards the target entity between the onset of the verb and the postverbal material was approximately 20% higher on transitive trials than intransitive trials. This was taken as evidence that verb-specific subcategorisation information (relating to transitivity) facilitated the prediction of an upcoming direct object. Arai and Keller (2013) also contrasted looks to the target at the site of the postverbal preposition/conjunction in conditions 1b and 1c. Compared to 1c (their control condition), they found that condition 1b elicited more anticipatory looks to the “prince” (i.e., the most plausible complement of the unfolding prepositional phrase). For simplicity, we decided to focus on the transitivity manipulation, and therefore omitted condition 1b from our design.

Using a translated subset of materials from Arai and Keller (2013), we asked to what extent listeners exploit the equivalent syntactic affordance in Dutch, allowing them to pre-activate a postverbal direct object upon hearing a transitive verb. We were also interested in whether such a syntactic prediction effect would be related to individual differences in literacy experience. Usage-based models of syntactic processing predict specific and direct effects of written language

input on performance (Wells et al., 2009; Montag & MacDonald, 2015). ‘Book language’ may be a particularly rich source of input because of its syntactic complexity and diversity compared to typical conversational speech (Kroll, 1977; Roland et al., 2007). Consistent with this account, the predictive parsing of spoken passive sentences showed a unique contribution of literacy experience in non-reading impaired adults (Favier et al., under review). The current study used the same group of participants to explore a different aspect of syntactic prediction. Based on previous results, we predicted that highly experienced literates would be more efficient at exploiting syntactic cues (here, verb-specific subcategorisation information) in order to anticipate postverbal material (here, direct objects).

## **Method**

### *Participants*

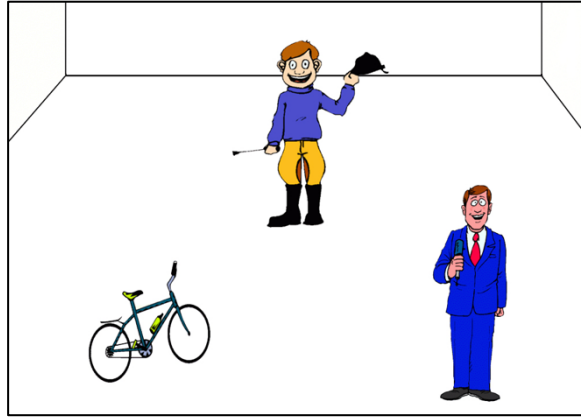
38 native Dutch speakers participated in the current eye-tracking experiment as part of a larger study (reported in Chapters 3 and 4 of this thesis). The sample comprised two groups: 20 participants (mean age 26.1) who performed in the top quartile on a composite measure of literacy experience (henceforth high literacy experience, HLE), and 19 participants (mean age 24.2) who scored in the bottom quartile (low literacy experience, LLE). The statistically derived index of literacy experience is described in detail in Chapter 2. For a descriptive summary of the groups, see Chapter 4 (Table 1). One participant from the HLE group was excluded because the eye tracker failed to calibrate to their eyes.

### *Materials*

We adapted a subset of materials from Arai and Keller (2013, Experiment 1). These included a set of 24 visual scenes, each containing three cartoon images which were arranged as shown in Figure 1. The images corresponded to subject, target, and distractor and were counterbalanced for position across the scenes.<sup>12</sup>

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<sup>12</sup> In four of the visual scenes, the original cartoon depicting a female character was replaced with its male counterpart (e.g., a male opera singer instead of a female opera singer), to correspond to the masculine gendered nouns that were inadvertently used by default in the Dutch translation.



**(a) Transitive**

De verslaggever ontbood plotseling de jockey.

*The reporter suddenly summoned the jockey.*

**(b) Intransitive**

De verslaggever siste plotseling en de jockey schopte tegen de fiets.

*The reporter suddenly hissed, and the jockey kicked the bicycle.*

**Figure 1.** Example experimental item, with visual scene and accompanying sentences for each experimental condition: Transitive (a) and Intransitive (b).

There was one transitive sentence (a) and one intransitive sentence (b) to accompany each visual scene. As mentioned above, we omitted one experimental condition from the original study. The resulting list of 48 sentences was translated from English into Dutch. To provide optimal conditions for verb-mediated anticipation, it was important that all verbal material preceded the target word. Where a verb's translation equivalent required a clause-final particle (e.g., *De tennisser trok het model aan*, *The tennis player attracted the model*), we therefore substituted a non-separable alternative (e.g. *De tennisser vergaf het model*, *The tennis player forgave the model*).

We used a monolingual Dutch dictionary (Sterkenburg, 2002) to check the subcategorisation frames of the 48 critical verbs, and our final list was verified



by a Dutch linguist.<sup>13</sup> For verbs in the transitive set, we ensured that only transitive entries were listed in the dictionary, and that an animate direct object was strongly preferred. When a translation equivalent verb did not satisfy these criteria, we selected an appropriate substitute. As in the original English stimuli, some Dutch verbs in the intransitive set also had a transitive entry (e.g., *zij fluisterde zijn naam*, *she whispered his name*). However, as Arai and Keller (2013) note, none of the pictured entities were legitimate direct objects for these verbs (e.g., *De non fluisterde de kunstenaar/waterkoker\**, *The nun whispered the artist/kettle\**).

Arai and Keller (2013) included sentence-initial adverbials (e.g., “Surprisingly, the nun punished the artist”) with the aim of providing some context for the events described. However, word order constraints in Dutch require inversion of subject and verb following a sentence-initial adverbial, which did not fit the requirements of our design. We therefore used an alternative position for the adverbial, immediately after the verb (e.g., *De non strafte-V stiekem-ADV de kunstenaar*, *The nun secretly punished the artist*). We selected ten adverbials that were licensed in this position and were semantically similar to the eleven used in the original study. The resulting sentences were judged to be reasonably natural sounding by native speakers of Dutch. It should be noted that placing the adverbial between the cue (verb) and target noun extended the time window for listeners to launch anticipatory eye-movements.

We also constructed 48 filler items, each comprising a visual scene and a sentence that mentioned one, two, or all three of the entities displayed. We used cartoon images similar in style to the experimental items, while ensuring that no entity appeared more than once across the experiment. As in Arai and Keller (2013), the filler sentences were copula verb constructions (e.g., *De koelkast was duidelijk zwaarder dan de platenspeler*, *The fridge was clearly heavier than the record player*), and contained no transitive or intransitive verbs. For consistency with the experimental items, the fillers included the same set of post-verbal adverbials.

The sentences were spoken by a female native speaker of Dutch with neutral intonation. Recording took place in a soundproofed booth using a Sennheiser

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<sup>13</sup> We thank Brigitte Bauer for her advice on verb transitivity in Dutch.

ME64 microphone (44kHz mono format; 16 bit sampling resolution). The average sentence duration was 3339ms. Table 1 shows the mean verb durations by condition, as well as the mean durations of the critical window between verb onset and post-verbal noun onset. Transitive verbs were on average longer than intransitive verbs, while the critical window for prediction was longer in the intransitive condition, likely due to the presence of an extra word (the conjunction “en”).

Condition	Verb duration (SD)	Critical window duration (SD)
Transitive	637 (117)	1316 (262)
Intransitive	527 (74)	1539 (215)

**Table 1.** Mean verb and critical window durations for each experimental condition in milliseconds, with standard deviations (SD).

We created two experimental lists, both containing all 24 experimental items. The lists comprised the same set of 24 visual scenes, while the accompanying auditory sentences alternated between their transitive and intransitive versions, such that across the two lists, each item occurred once in the transitive condition and once in the intransitive condition. As a result, participants saw 12 items per condition.

### *Procedure*

Participants were tested individually in a soundproofed experiment booth. We used an SR Research EyeLink 1000 tower-mounted eye tracker to record eye movements. Odd-numbered participants were assigned to experimental list 1 (n=18) and even-numbered participants to list 2 (n= 19). Participants were instructed to listen to the sentences (presented via headphones) and to avoid looking away from the screen. There was no explicit task to perform other than ‘look and listen’, a widely used protocol in visual world prediction studies, which is found to yield the same effects as more active tasks (Mishra et al., 2013). Each trial began with a one-second fixation dot, followed by a short preview of the visual scene before playback of the auditory sentence was initiated. The total

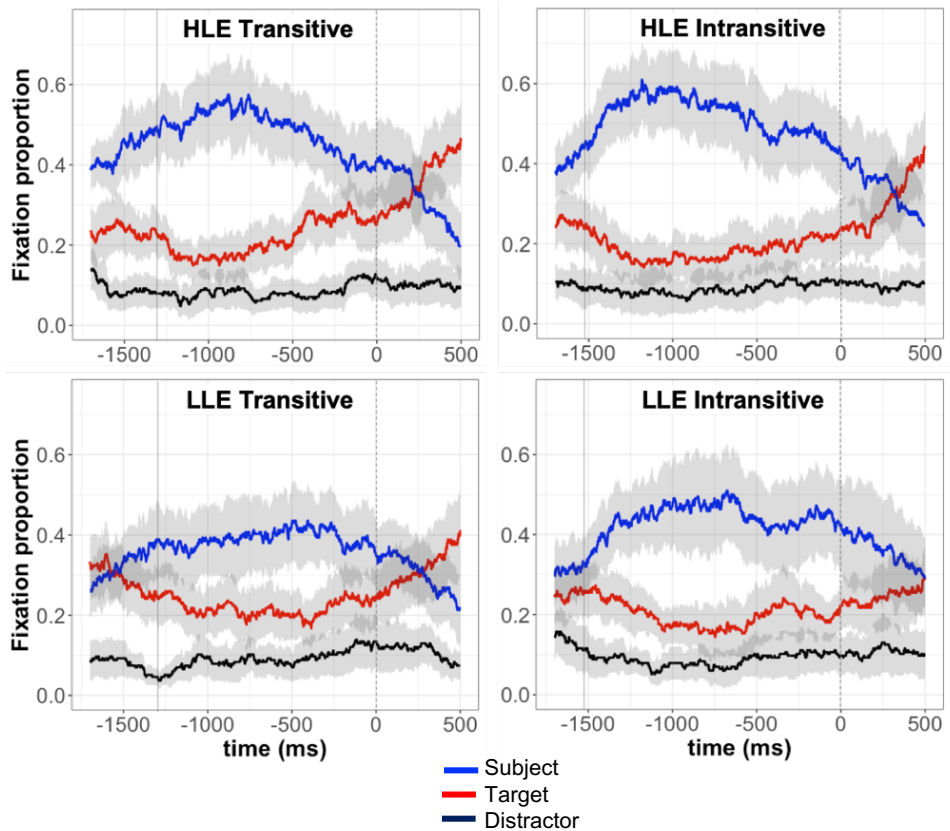
preview time prior to the onset of the verb in the speech signal was always two seconds. The visual scene was displayed until 2500ms after the onset of the target noun. The order of trials was automatically pseudo-randomised for each participant, with the constraint that at least one filler preceded every experimental trial, and the experiment began with two fillers. There were 72 trials in total, of which 33% were experimental (transitive/intransitive) and 67% were fillers. The testing session lasted approximately 15 minutes, including eye-tracker calibration.

### **Analysis and results**

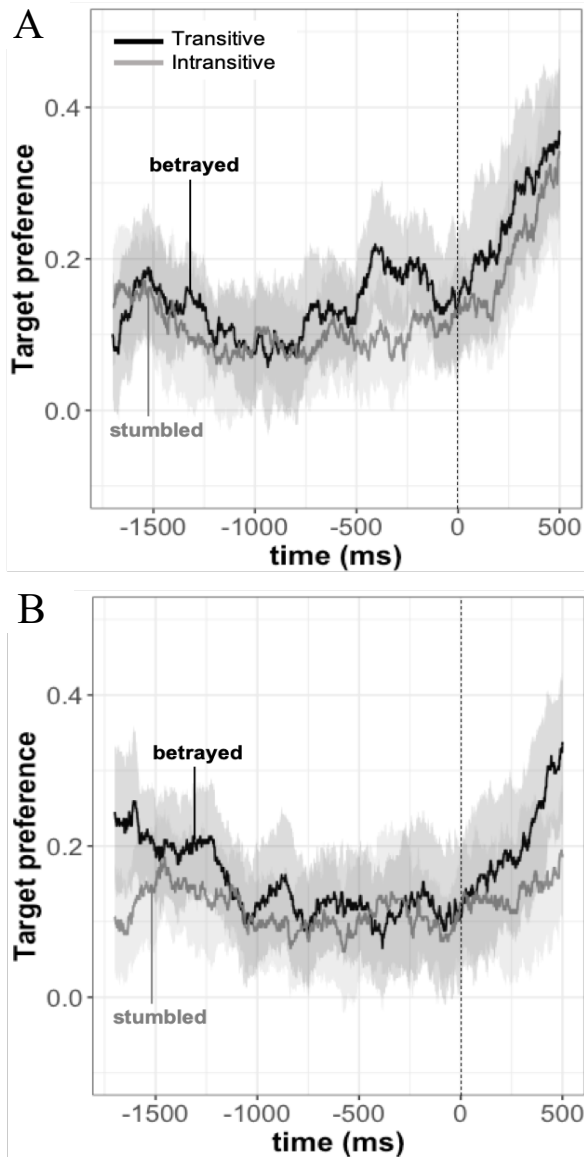
The eye-tracking data were processed in Eyelink DataViewer, using a built-in algorithm that identified fixations, saccades and blinks. Eleven out of 888 trials were missing due to track loss. Fixation locations were automatically coded as subject, target, distractor, or background, corresponding to the manually pre-defined interest areas for each visual scene. The rate of background fixations was 7% in the HLE group and 10% in the LLE group. In preparation for the analyses, we established the timing of each fixation relative to the onset of the target word in the speech signal.

Figure 2 shows the time course of fixation proportions to the target (red line), subject (blue line), and distractor (black line), plotted by experimental condition (i.e., verb type) and literacy group. The time window of interest extends from verb onset to target onset (time zero), indicated respectively by dotted and dashed lines in Figure 2. In Figure 3, the time course of target preference is plotted by experimental condition for the HLE group (Panel A) and LLE group (Panel B). To calculate target preference, we subtracted the proportion of distractor fixations from the proportion of target fixations at each time step in the Transitive (black line) and Intransitive condition (grey line). Subject fixations were not included in this calculation. Figure 2 suggests that the rate of target fixations remained relatively low throughout the critical window, regardless of verb transitivity. This pattern appears largely similar across groups, although the HLE group showed a slight increase in target preference on transitive trials (Figure 3, Panel A), which

peaked at approximately 0.2 (i.e., 20% more target fixations than distractor fixations) in the final 500ms before target word onset. It should be noted that for both groups, target preference in the intransitive (control) condition is consistently above zero.



**Figure 2.** Plotted fixation proportions to subject, target and distractor entities for the high literacy experience (HLE) group and the low literacy experience (LLE) group in Transitive and Intransitive conditions. The grey shaded areas represent by-participant 95% confidence intervals, computed at each 1ms sampling step (Masson & Loftus, 2003). The vertical dotted lines represent the average onset of the verb in the speech signal. The vertical dashed lines indicate the acoustic onset of the target word (time zero).



**Figure 3.** Target preference plotted by verb type for the HLE group (Panel A) and the LLE group (Panel B). Target preference is the difference between target fixation proportions and distractor fixation proportions at a given time point. By-participant 95% confidence intervals, shaded in grey, were computed at each 1ms sampling step. Mean verb onset times are labelled for each condition (translation equivalent verbs). The dashed lines represent the acoustic onset of the target word (time zero).

Table 2a summarises the proportion of target and distractor fixations by condition and by group. Fixation proportions were calculated for the period between the acoustic onset of the transitive/intransitive verb and the onset of the target word. Both onsets were adjusted by 200ms to account for the typical latency of language-mediated eye movements (Saslow, 1967). Across literacy

groups and experimental conditions, looks to the target generally constitute a small proportion of the recorded fixations (as seen in Figure 2). Both groups show a slight numerical increase in target fixations on transitive trials compared to intransitive trials. To estimate the magnitude of the change, we calculated effect size (Cohen's *d*) for each group, based on the mean difference between target and distractor fixations in the transitive versus intransitive condition. The Cohen's *d* values reported in Table 2b suggest that verb transitivity had a minimal effect on anticipatory eye-movements (indexed as the proportion of looks to the target relative to the distractor prior to target word onset). The effect size for the LLE group is close to zero. While Cohen's *d* is numerically larger in the HLE group, the magnitude of any transitivity effect remains very small.

Group	Intransitive		Transitive	
	Target	Distractor	Target	Distractor
HLE	.19 (.21)	.09 (.17)	.22 (.24)	.08 (.17)
LLE	.20 (.24)	.08 (.16)	.22 (.25)	.09 (.17)

**Table 2a.** Descriptive summary of target and distractor fixation proportions by verb type and by group, calculated for the period between verb onset (+200ms) and target onset (+200ms). HLE = High Literacy Experience; LLE = Low Literacy Experience. Standard deviations are shown in brackets.

Group	Mean difference	SE	Cohen's <i>d</i>
HLE	.04	.07	.12
LLE	.01	.10	.04

**Table 2b.** Size of verb transitivity effect (Cohen's *d*) on anticipatory eye-movements for each literacy experience group. Mean difference is the difference between target and distractor fixations in the transitive condition versus the intransitive condition. SE = Standard Error of the mean difference (between conditions).

We fit a linear mixed-effects model to the eye-tracking data from experimental trials, using the *lme4* package in R version 1.2.1335 (Bates et al., 2014; R Core Team, 2019). The dependent variable was the log odds of fixating the target entity minus the log odds of fixating the unrelated distractor. This was calculated by participant and by item for the period described above. The fixed factors in the model were verb type (Intransitive/Transitive) and literacy experience group (Low/High) as well as their interaction. Mean-centred non-verbal IQ and verbal working memory scores were entered as covariates. Finally, we included random intercepts for participant and item, as well as a random effect of verb type by participant (n=37) and by item (n=24). Table 3 summarises the model results. The positive intercept reflects the LLE group's tendency to fixate the target more often than the distractor in the intransitive condition, as previously observed. Importantly, we did not find evidence for a main effect of verb type on target preference (zero falls near the centre of the 95% confidence interval). This is consistent with the low effect size estimates in Table 2b. Due to the absence of a statistically meaningful effect of verb type, we were unable to detect any interaction with literacy experience. Finally, there was no evidence for a relationship between target preference and our control covariates, non-verbal IQ and verbal WM.

Predictor	Coefficient	SE	<i>t</i> value	95% CI
Intercept	2.28	0.46	4.98	1.38, 3.17
Verb Type: Transitive	0.14	0.46	0.31	-0.75, 1.03
Literacy Experience: High	-0.23	0.61	-0.37	-1.42, 0.97
Non-verbal IQ	0.03	0.04	0.77	-0.05, 0.11
Verbal working memory	0.07	0.10	0.70	-0.13, 0.26
Verb Type: Transitive x Literacy Experience: High	0.32	0.62	0.52	-0.89, 1.53

**Table 3.** Summary of fixed effects in the linear mixed-effects model (N = 877). The intercept represents the difference between looks to target and to the

unrelated distractor during the critical time window on an intransitive trial, for an LLE participant with average non-verbal IQ and verbal working memory.

## Discussion

The current study aimed to replicate the syntactic prediction effect reported by Arai and Keller (2013, Experiment 1) in Dutch, and asked whether such an effect would be mediated by participants' literacy experience. In their visual world eye-tracking experiment, Arai and Keller found that verb-specific subcategorisation information (transitivity) facilitated the prediction of post-verbal direct objects in English. A comparable result was expected for Dutch, in which the same syntactic constraint exists (i.e., that transitive verbs require direct objects). Specifically, we predicted that Dutch listeners would be more likely to launch anticipatory eye movements to the plausible direct object entity upon hearing a transitive verb compared to an intransitive verb (which does not license a direct object). While the eye-tracking data showed a tendency in the expected direction, the effect of verb type was not statistically meaningful. Clearly, this precluded our ability to detect robust literacy-related differences in syntactic prediction of the kind reported by Favier et al. (under review). The numerically larger (though still small) effect size for highly experienced literates nevertheless suggested a tendency in line with those results.

A straightforward explanation for the unsuccessful replication was the small size of the original effect and, relatedly, the statistical power required to replicate it. Arai and Keller (2013) found a small but statistically robust difference between the logit of gaze probabilities to the target entity on transitive versus intransitive trials. Here we refer only to the intransitive condition relevant to the current study, in which a conjunction followed the verb. Despite comparable sample sizes (37 participants in the current study versus 33 in the original study), there may have been insufficient power to detect a statistically meaningful effect of verb transitivity in our study. It is possible that the numerical trend we observed towards increased target fixations on transitive trials would have emerged as robust in a much larger sample. Such an effect would likely be very small,



however, suggesting that listeners may not routinely use verb transitivity information to generate predictions during everyday sentence processing.

Another possible contributing factor to the present results was that the intransitive verbs did not provide a good neutral control condition. In fact, target preference showed a similar upward trajectory on both intransitive and transitive trials, curtailing the scope for measuring a differential effect of verb transitivity on anticipatory eye movements. Arai and Keller (2013) also observed increasing gaze probability to the target in their control condition, though to a slightly lesser degree. It may be that properties of the experimental materials contributed to this trend in both studies. For example, regardless of verb condition, experimental sentences always mentioned both human characters in the accompanying visual scene. It is conceivable that participants became attuned to this, and when the visual scene contained two human characters, predictively directed their gaze to the one yet to be mentioned, independent of syntactic affordances. In addition, although no verbs in the intransitive condition licensed an animate direct object, some actions (e.g., “whispered”) implied a second animate participant (i.e., a prepositional object) and could therefore have triggered anticipatory looks to a compatible entity in the visual scene. In short, extraneous affordances of the visual and linguistic stimuli likely boosted target fixations in the control condition, possibly masking any prediction effect linked to the experimental manipulation.

### *Conclusion*

Arai and Keller (2013) presented one of a small number of studies to date focusing on syntactic prediction during spoken sentence processing. Notably, their results highlighted a role for lexically specific information in the early stages of syntactic analysis. We did not succeed in replicating the reported prediction effect in Dutch, despite the syntactic parallels with English. While we observed a numerical trend in the expected direction, the effect of verb transitivity on anticipatory eye movements to post-verbal arguments was not statistically robust. The present results did not allow us to draw conclusions about the contribution of literacy experience to verb-mediated syntactic prediction.

## 6. Proficiency modulates between- but not within-language syntactic priming<sup>14</sup>

The oldest of the Celtic language family, Irish differs considerably from English in the syntactic domain, notably with respect to word order and case marking. In spite of differences in surface constituent structure, less restricted accounts of bilingual shared syntax predict that processing datives and passives in Irish should prime the production of their English equivalents. Furthermore, this cross-linguistic influence should be sensitive to L2 proficiency, if shared structural representations are assumed to develop over time. In Experiment 1, we investigated cross-linguistic syntactic priming from Irish to English in 47 bilingual adolescents who are educated through Irish. Testing took place in a classroom setting, using written primes and written sentence generation. We found that priming for prepositional-object (PO) datives was predicted by self-rated Irish (L2) proficiency, in line with previous studies. In Experiment 2, we presented translated materials to an English-educated control group (n=54) and found a within-language priming effect for PO datives, which was not modulated by English (L1) proficiency. Our findings are compatible with current theories of bilingual language processing and L2 syntactic acquisition.

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<sup>14</sup> Adapted from Favier, S., Wright, A., Meyer, A., & Huettig, F. (2019). *Proficiency modulates between-but not within-language structural priming*. *Journal of Cultural Cognitive Science*, 3(1), 105-124.

## Introduction

Syntactic priming and, perhaps most intriguingly, cross-linguistic syntactic priming, can be used as tools to investigate how the mind represents abstract syntactic information. While theories differ as to the underlying mechanisms of the effect, the persistence of syntactic structures within and between languages is well attested in the literature. To cite a classic example, Bock (1986) found that after hearing and repeating a sentence like *The corrupt inspector offered a deal to the bar owner*, participants were more likely to use a prepositional-object dative to describe an unrelated pictured event (e.g., *The girl is handing a valentine to the boy*), compared with its alternative, the double-object dative (*The girl is handing the boy a valentine*).

Since it was first reported over thirty years ago, the effect of recent syntactic experience on subsequent production has been demonstrated with a variety of tasks, syntactic structures, and languages (see Mahowald et al., 2016, for a meta-analysis). These effects, which occur in the absence of lexical or semantic repetition (Bock, 1989; Bock & Loebell, 1990), are taken as evidence for the representation of abstract structure in the language processing system (Branigan & Pickering, 2017). Syntactic priming from one language to another suggests a further level of abstraction at which some syntactic information is shared across languages.

Theoretical accounts of shared syntax in the bilingual mind are supported to varying degrees by the cross-linguistic syntactic priming literature (see Van Gompel & Arai, 2018, for a review). One issue still subject to debate is the importance of syntactic congruency between languages, with implications for the scope of shared syntax in bilingualism. While some studies have found that the cross-linguistic priming effect depends on both languages sharing the same surface constituent structure (e.g., Loebell & Bock, 2003; Bernolet et al., 2007), others have demonstrated syntactic priming between languages with major typological differences such as Korean and English (Shin & Christianson, 2009), and Scottish Gaelic and English (Kutasi et al., 2018).

### *Language proficiency*

A recent empirical and theoretical focus concerns the role of L2 proficiency in cross-linguistic syntactic priming. Hartsuiker and Bernolet (2017) hypothesised that L2 syntactic acquisition is characterised by the development of abstract structural representations that progressively become less language-specific and more integrated with existing representations in L1. The presumed result is that similar structures in L1 and L2 share representations, which are activated during syntactic coding in either language and thus facilitate cross-linguistic syntactic priming. It follows from this account that the magnitude of the priming effect should be modulated by L2 proficiency, if higher proficiency is associated with more abstract, language-independent representations for the target structure.

An established index of proficiency is participants' self-rated language skills across modalities on a 7-point scale (found to correlate with direct measures; Lemhöfer & Broersma, 2012). There is some evidence to support the contribution of L2 proficiency to syntactic priming from L1 to L2 and also within L2 (reviewed by Hartsuiker & Bernolet, 2017). However, this has not been a consistent finding in the literature to date (e.g., Hartsuiker et al., 2016; Kutasi et al., 2018). We consider these studies in more detail in the discussion section.

### *Less studied populations in psycholinguistic research*

The importance of gathering data from less studied populations is increasingly acknowledged in the cognitive sciences. In the domain of language processing, broadening the relevance of research at the global level requires an active focus on minority cultures and language communities. Multilingualism is the norm rather than the exception across most of the world, and speakers of minority languages account for a large part of this phenomenon (e.g., in India; Pandharipande, 2002). These communities are by their nature small, sometimes difficult to access, and may require alternatives to traditional lab-based testing. Regardless of the challenges, data from previously unstudied groups is essential to develop theories of language processing that take into account the diversity of human language and cognitive abilities.

In a literature largely dominated by majority languages, it is not surprising that speakers of Irish Gaelic (henceforth, Irish) have not (to our knowledge) been

a focus of any language processing research to date. Yet, the changing demographic distribution of the speaker community, as well as the typological distance between Irish and English, make this an interesting case study in bilingualism. Irish is the national language of the Republic of Ireland and a recognised minority language in Northern Ireland. It is the oldest of three Goidelic languages (the others being Scottish Gaelic and Manx), which belong to the Celtic branch of Indo-European. Notable typological differences from English include verb-subject-object (VSO) word order and the use of case marking. Despite its official status as the first language of Ireland, Irish is more widely spoken as an L2, with proficiency and frequency of use varying greatly across speakers. In a survey published by the European Commission, 22% of respondents in Ireland reported some ability to speak Irish, while only 3% described it as their first language (Eurobarometer, 2012). L1 Irish-speaking communities exist predominantly in western coastal regions of Ireland, collectively known as the Gaeltacht. While the numbers of L1 speakers in these rural communities is in rapid decline, the growing popularity of Irish-medium education outside of the Gaeltacht has produced a generation of ‘new speakers’ of Irish, concentrated in urban areas (Slatinská, 2017).

In this paper, we investigate cross-linguistic syntactic priming in a sample of ‘new speakers’ of Irish: bilingual adolescents attending an urban, Irish-medium secondary school. Adolescents arguably constitute another under-represented group in the language processing literature, often falling outside the remit of both developmental and adult studies. We cannot assume that findings from the adult literature would necessarily generalise to adolescent language processing, especially given the common practice of sampling university undergraduates, who represent a relatively restricted range of language experience and ability. Adolescent performance on language processing tasks is likely to be subject to more variability than is seen in the typical, highly educated adult sample.

### *The current study*

This paper focuses on two well-studied structures in the cross-linguistic syntactic priming literature: datives and passives. Dative priming usually relies on the structural alternation whereby the same ditransitive event can be described using

either a double-object (DO) or prepositional-object (PO) construction (e.g., *The monk gave the cowboy a cake* vs. *The monk gave a cake to the cowboy*). In contrast to English, Irish permits only one type of dative (1), which corresponds most closely to the English PO construction in terms of constituent order (Direct Object + Indirect Object). However, surface constituent structure diverges from the English PO, since Irish uses case marking, rather than a preposition, to specify the indirect object (the dative-inflected article *don*, which has no correspondence in English). Furthermore, as per Irish VSO word order, the main verb (*Thug*, “gave” in 1) occurs sentence-initially, marking a salient difference from the English.

1. Thug an manach cáca don buachaill bó.  
     Gave the monk cake to the cowboy  
     “The monk gave a cake to the cowboy”

The Irish passive (2) shares some structural features with its English equivalent. Aside from the initial position of the verbal auxiliary *Bhí* (“was”), the Irish passive construction has a similar constituent order to English: patient in the subject position, followed by a participle (*buailte*, “hit” in 2), and a prepositional “by” phrase that specifies the agent (*ag* corresponds to “by”). As Irish passives are very rarely used in the present tense, we focus on the past tense in this study.

2. Bhí an fear grinn buailte ag an mairnéalach.  
     Was the clown hit by the sailor  
     “The clown was hit by the sailor”

Using a comprehension-to-production priming paradigm, we examined the extent to which reading dative and passive sentences in Irish influenced students’ subsequent syntactic choices in English, in a written sentence generation task (Experiment 1). As demonstrated above, Irish datives and passives overlap with their English counterparts to varying degrees, but it is clear that surface structure is not identical across languages. We based our predictions on previous evidence for cross-linguistic priming in the absence of shared surface structure (Kutasi et

al., 2018; Shin & Christianson, 2009, but see Bernolet et al., 2007). Firstly, we predicted that Irish dative sentences would prime the production of PO datives in English. Specifically, we expected to see an increase in the proportion of PO responses following an Irish dative prime compared to a structurally unrelated baseline condition (comprising three conjoined noun phrases). Secondly, on active-passive trials, we predicted an effect of prime type on the structure of responses, such that more English passive sentences would be produced following an Irish passive prime than an active or baseline prime (two conjoined noun phrases). As the strongly preferred canonical form, we did not expect to observe a priming effect for actives (production too near ceiling). We included a measure of self-rated Irish proficiency in order to test the prediction that cross-linguistic syntactic priming is modulated by L2 proficiency.

Experiment 2 is a within-language control experiment, which we conducted with Irish adolescents receiving their education through English. Experiment 2 used the same design and procedure as Experiment 1, but we presented prime sentences in English instead of Irish. This between-experiment comparison allowed us to examine the specific contribution of the cross-linguistic design to our results in Experiment 1. We were also interested in the contribution of L1 proficiency to within-L1 syntactic priming. Due to anticipated ceiling effects on the self-rated proficiency measure, we used participants' most recent standardised English exam grades as a proxy for L1 proficiency in Experiment 2.

The Junior Certificate is the standardised assessment of academic attainment in Ireland, which participants had completed between 6 and 18 months prior to the current study. Although the Junior Certificate English curriculum also encompasses literature and media studies, four of the seven components of the exam directly assess reading comprehension and functional writing, and quality of written language is applied as a marking criterion to all components. Aspects of linguistic competence highlighted in the marking scheme include syntactic complexity, discourse structure, coherence, and spelling. We therefore considered Junior Certificate English grades as a reasonable proxy for L1 proficiency, providing an overall picture of participant's language aptitude, despite the potential noise introduced by less relevant components of the

assessment such as literature. These grades were included as an exploratory covariate in the priming analyses in Experiment 2.

## **Experiment 1**

We investigated syntactic priming from Irish to English, using written sentence generation in a classroom setting. Ethical approval for the study was granted by the Education and Health Sciences Research Ethics Committee at the University of Limerick, Ireland.

### **Method**

#### *Participants*

Forty-seven English-Irish bilinguals (27 females) gave informed consent to participate in the study. The participants, aged 16-17 years ( $M=16.37$ ,  $SD=0.49$ ), were recruited from an Irish-medium secondary school in Dublin, Ireland. Written consent was obtained both from participants and their parents/guardians. We used a questionnaire (adapted from Kutasi et al., 2018; Appendix B) to assess Irish language history, frequency of use, and self-rated proficiency across speaking, listening, reading, and writing on a 7-point scale. Table 1 summarises the results of the questionnaire, which was completed by thirty-six participants. The overall mean for self-rated Irish proficiency across modalities was 5.98 ( $SD=0.70$ ). As they received their education through Irish, all participants engaged in Irish conversation daily, and twenty participants also reported speaking Irish at home. The majority were sequential bilinguals, who began acquiring Irish at school, while three had acquired Irish and English simultaneously from birth. Participants were also asked to provide their Junior Certificate exam results for Irish and English. Of those who provided their Junior Certificate exam grades, all had achieved either a B (23%) or a C (77%) in English at higher level.



Variable	Mean (SD)	Range
Age at testing	16.37 (0.49)	16 – 17
Age when began acquiring Irish (years)	3.45 (1.22)	0 – 5
Speaking proficiency (7pt)	6.03 (0.86)	4 – 7
Listening proficiency (7pt)	6.42 (0.61)	5 – 7
Reading proficiency (7pt)	6.03 (0.98)	4 – 7
Writing proficiency (7pt)	5.51 (1.12)	3 – 7

**Table 1.** Profile and self-rated Irish language proficiency of participants in Experiment 1 (n=36).

### *Design and Materials*

There were two sets of experimental materials, targeting active/passive priming and PO dative respectively. The items of the two sets were mixed, together with a set of filler items. Each item consisted of a prime picture, a prime sentence, and a target picture with a written verb printed above it. These elements are described in more detail in the following sections. Note that prime and target pictures and target verbs were displayed on a screen to the entire group of participants simultaneously. Written prime sentences were presented in participants' answer booklets. Their cover task was to provide a true/false response to each sentence, based on congruity with the displayed picture. The answer booklet contained empty spaces for participants' written descriptions of target pictures.

### Active-passive set

We created 48 transitive items for the active-passive set, which consisted of prime sentences in Irish and their corresponding pictures, paired with target pictures to elicit sentences in English. Picture stimuli were black and white line drawings of transitive events involving human agents and patients (adapted from Bernolet, et al., 2016, and Kutasi et al., 2018). As in Kutasi et al. (2018), patients always appeared on the left, to increase the likelihood of eliciting passives.

There were three versions of each prime sentence in Irish, corresponding to the three experimental conditions: Active, Passive, and Baseline (see Figure 1).

Prime sentences in the Active condition described pictured events using the canonical order (verb + agent + patient). Prime sentences in the Passive condition described the same events using a passive construction with the agent in a prepositional phrase (see Example 2 in the Introduction). To provide a neutral control condition without any verb, Baseline sentences were noun phrase conjunctions referring to the two characters depicted, e.g., *Gadaí agus póilín*, “A burglar and a policeman”). The characters were named in the same order that they appeared in the pictures, from left to right. Noun phrases used the indefinite article (unmarked in Irish) for greater naturalness.



#### 1a. Active

Lean an póilín an gadaí  
 Chased the policeman the burglar  
 “The policeman chased the burglar”

#### 1b. Passive

Bhí an gadaí leanta ag an bpóilín  
 Was the burglar chased by the policeman  
 “The burglar was chased by the policeman”

#### 1c. Baseline

Gadaí agus póilín.  
 A burglar and a policeman

**Figure 1.** Example item from the active-passive set: Prime picture (top), corresponding Irish prime sentences, and target picture (bottom) with printed verb to elicit an English sentence.

Prime pictures depicted six actions: punch, chase, kiss, push, tickle, and pull. We selected a further six actions for the target pictures, to elicit English sentences: carry, weigh, clean, kick, follow, and hit. The respective target verb

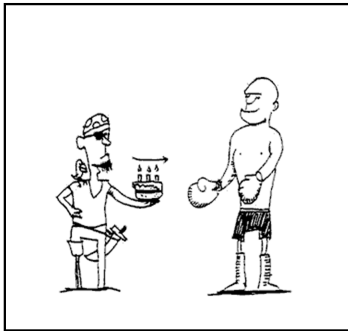
was printed in English above each target picture. Across the item set, comprising 48 prime pictures and 48 target pictures, there were eight different depictions of every action. The order of prime pictures was pseudo-randomised such that the same action was depicted no more than twice consecutively. To each prime picture we then assigned a different target picture. The final item set contained most possible combinations of prime and target actions, except for pairs with too close a semantic relationship (e.g., chase-follow; punch-hit), which we excluded.

A set of twenty human characters (e.g., sailor, dancer, monk) appeared as the agents and patients of both prime and target actions. Agents and patients were repeated across items, with the constraint that a character could appear no more than twice in the same role for each target action. Within items, there was no repetition of action or characters between prime and target pictures.

### Dative set

We created 48 dative items with the same components as active-passive items (prime sentences in Irish, prime pictures, and target pictures). Picture stimuli were black and white line drawings of ditransitive events, adapted from Bernolet et al. (2016). They involved a human agent, an object theme, and a human recipient. In dative pictures, the agent always appeared on the left, the theme in the middle, and the recipient on the right.

There were two versions of each prime sentence, corresponding to two experimental conditions: Dative and Baseline (see Figure 2). Sentences in the Dative condition took the Irish canonical form (verb + agent + theme + recipient), which corresponds most closely to the prepositional-object dative in English. As in the active-passive set, the Dative Baseline condition used conjoined noun phrases without a verb. However, these consisted of three noun phrases rather than two, to match the number of entities named in the Dative condition (Baseline naming order: agent, recipient, and theme).



## 2a. Dative

Thug an foghláí mara cáca don dornálaí

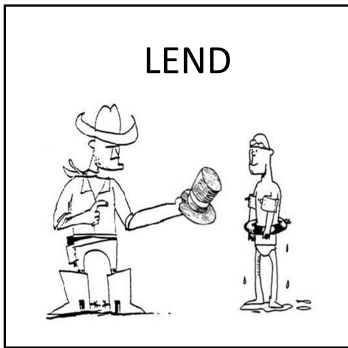
Gave the pirate cake to the boxer

“The pirate gave a cake to the boxer”

## 2b. Baseline

Dornálaí, an foghláí mara, agus cáca

A boxer, a pirate and a cake



**Figure 2.** Example item from the dative set: Prime picture (top), corresponding Irish prime sentences, and target picture (bottom) with printed verb to elicit an English sentence.

Prime pictures depicted six actions, corresponding to dative verbs that alternate in English: give, sell, show, pass, throw, and offer. We selected a further six alternating dative verbs as targets, and superimposed them on the target pictures: hand, lend, award, grant, owe, and allocate. There were 48 prime pictures and 48 target pictures, so every action appeared eight times across the item set. We avoided target verbs with a strong bias towards either the English prepositional-object (PO) or double-object (DO) dative, using results of a corpus analysis by Gries and Stefanowitsch (2004) to inform our selection. The overall rate of PO occurrences across all alternating dative verbs in the one-million-word ICE-GB corpus was 65%.

Table 2 shows the percentage of PO occurrences reported in that study for our selected prime and target verbs. Our target verbs ranked amongst the least biased

of all the alternating dative verbs analysed by Gries and Stefanowitsch. We also conducted a Google Books search to ensure that the transitional probabilities of DO and PO constructions were similar for each item, i.e., the probability of a target verb occurring adjacently to a given recipient versus a given theme.

Prime Verb	% PO	Target Verb	% PO
give	24.1	award	30.0
show	23.4	grant	28.6
offer	25.9	allocate	55.6
sell	92.1	owe	60.0
pass	93.6	hand	80.8
throw*	-	lend	65.0

**Table 2.** Percentage of PO occurrences for each prime and target verb, based on the one-million-word ICE-GB corpus. The overall rate of PO occurrences across all alternating dative verbs in the corpus was 65% (from Gries & Stefanowitsch, 2004, p. 106, Table 2). \*Gries and Stefanowitsch do not provide data on *throw*; however, it is attested as an alternating dative verb in other corpus analyses (e.g., Lapata, 1999).

The order of dative prime pictures was pseudo-randomised, as in the active-passive set, and each prime picture was paired with a target picture. As dative verbs inherently share semantic features, it was impossible to avoid some overlap in meaning within prime-target pairs. Prime and target actions therefore occurred in all combinations at least once across the dative set.

The human characters described above were used as agents and recipients in the dative set. These were repeated across items but did not perform the same role more than twice in any given action. Six object themes (cup, apple, jug, book,

banana, hat) were also repeated across items, but never appeared more than twice with the same verb. Within items, there was no repetition of actions or entities between prime and target pictures.

### Fillers

We used 48 additional filler items, comprising ‘prime’ pictures of two or more non-interacting entities, ‘prime’ noun phrases in Irish (e.g., *beirt mhanaigh*, “two monks”), and ‘target’ pictures of single entities. For consistency with the critical items, ‘target’ pictures in the filler set also appeared with a printed English verb. Fillers used only intransitive verbs, unlikely to elicit transitive or dative descriptions (e.g., walk). To facilitate the ‘True or False?’ cover task, all filler items contained mismatching ‘prime’ pictures and sentences. We shuffled picture/sentence pairs so that one or more of the entities depicted mismatched the written description.

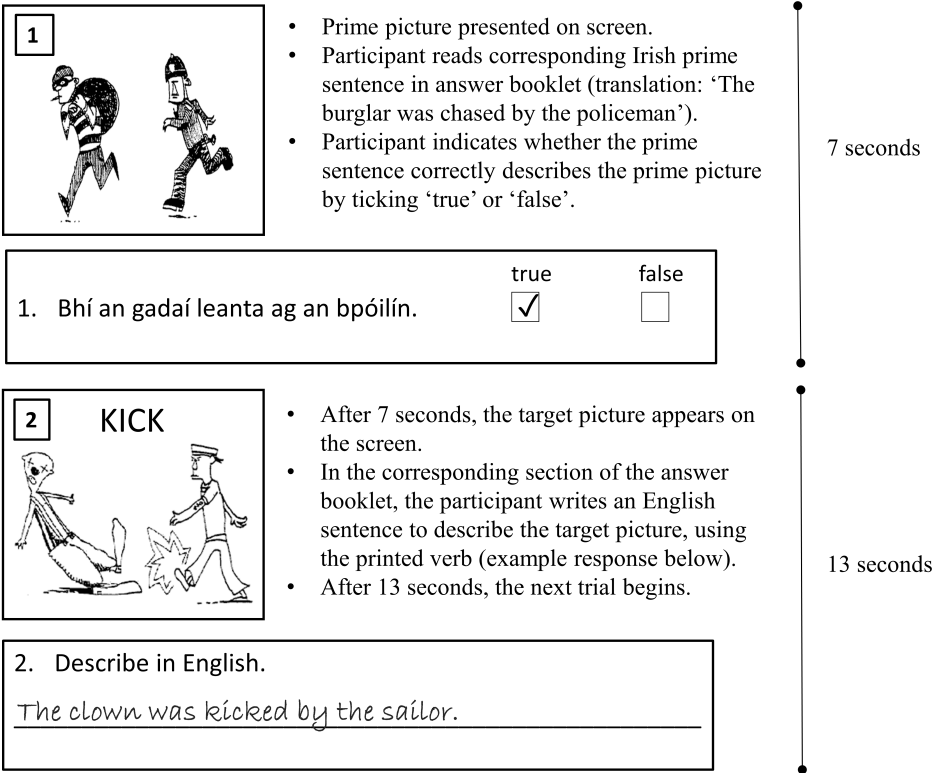
### List construction

The active-passive, dative, and filler sets were mixed to create a master list containing 144 items (288 pictures in total). The list was constructed such that no two transitive or dative items occurred consecutively. From the master list we derived six experimental lists using a 3x2 Latin square design, so that across the lists every transitive item occurred twice in each of the three experimental conditions (Active, Passive, and Baseline), and every Dative item occurred three times in each of the two experimental conditions (Dative and Baseline). The lists were pseudo-randomised such that all experimental conditions were evenly distributed within each list.

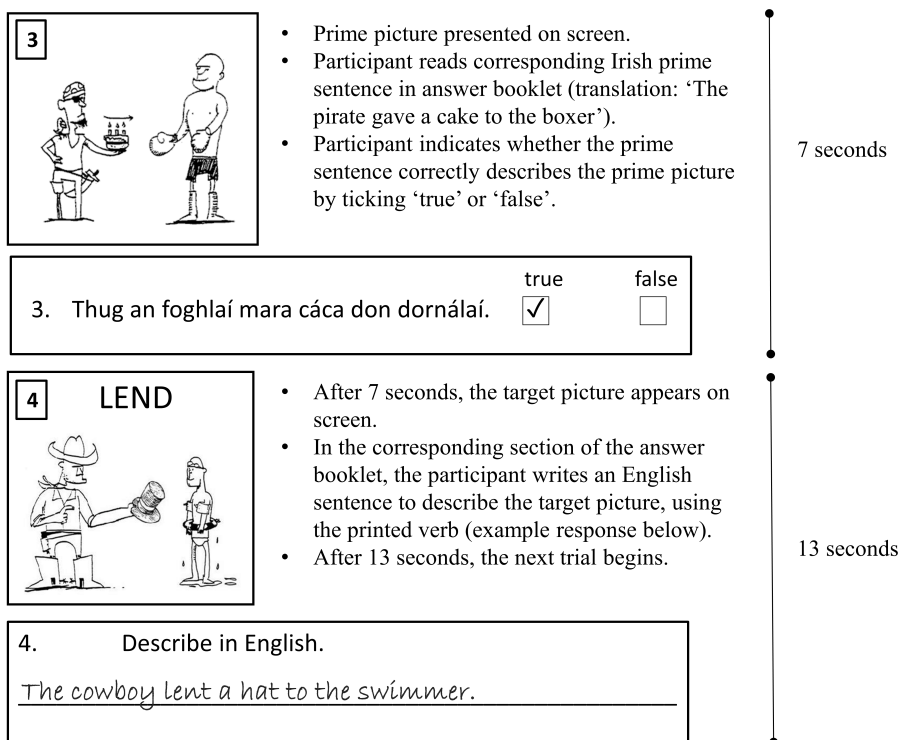
### Trial structure

We used a similar paradigm to previous comprehension-to-production priming studies (e.g., Bernolet et al., 2016), whereby participants alternately comprehend and produce picture descriptions. At the start of a trial, participants in the present study saw a prime picture displayed for 7 seconds, and read the corresponding Irish prime sentence, to which they responded ‘true’ or ‘false’. Next, a target picture was presented for 13 seconds, and participants wrote a sentence in English

to describe the picture, making use of the verb provided. The experiment consisted of 144 trials, preceded by six practice trials, which followed the same two-part structure. Figures 3 and 4 describe the composition and timing of transitive and dative trials respectively.



**Figure 3.** Example transitive trial structure (passive prime condition).



**Figure 4.** Example dative trial structure (dative prime condition).

### Presentation of materials

We created the alternating list of prime and target pictures in Microsoft PowerPoint, with target verbs printed in capital letters above the target pictures (Calibri, 60-point font). The pictures were numbered in order from 1 to 288. The number was displayed in a box in the top left-hand corner of the picture (Calibri bold, 44-point font). We set timings such that each prime picture was displayed for 7 seconds, immediately followed by a target picture, displayed for 13 seconds. The file was converted to a movie format, playable through QuickTime Player. We projected the movie onto a large screen at the front of the classroom, visible to all participants.

All prime and target pictures were presented to all participants in a fixed order, to facilitate group participation. Written prime sentences were presented to each participant individually in an answer booklet. Whereas the order of items was the



same for all participants, they read different versions of the prime sentence for a given item. The versions of the prime sentences presented in each answer booklet corresponded to one of the six experimental lists. There were therefore six unique answer booklets, each containing 144 prime sentences, two per page. The six versions of the booklet were randomly but equally distributed, so that eight participants completed each version.

Two boxes, labelled ‘true’ and ‘false’, appeared next to prime sentence in the answer booklet, to facilitate the picture verification cover task. Underneath each prime sentence was the printed instruction *Describe in English*, and empty space for participants to write down their description of the corresponding target picture (see Appendix A for page layout). The alternating prime sentences and blank spaces in the answer booklet were numbered from 1 to 288, corresponding to the numbers displayed in the top left-hand corner of prime and target pictures. This was intended to ensure that participants responded to each picture in the appropriate place in their answer booklets. The answer booklets were printed in black and white on A4 paper and all text was in 12-point Calibri font.

### *Procedure*

All participants were tested simultaneously in a large classroom in their school, seated at desks facing the front of the room. They attended to verbal instructions and completed the experimental tasks independently and in silence. The experimenter ran the session, with additional supervision provided by three class teachers.

Every participant received a pen and an answer booklet, containing only the written prime sentences, and empty spaces for responses to the prime task and the target task. All pictures were projected onto a large screen at the front of the classroom, with pictures and text visible to participants seated at the back of the room. Both oral and written instructions were provided at the start of the experiment, followed by six practice trials to familiarise participants with the task and characters. The practice block comprised one dative trial, one transitive trial with an active prime, and one with a passive prime. These were interleaved with three filler trials. After the practice block, participants had the opportunity to ask questions about the task.

After the experimental task (approximately 50 minutes), there was a 10-minute break. Participants then completed the Irish Language History Questionnaire (see Appendix B). The whole session lasted 1 hour and 30 minutes.

## Results and discussion

Overall, participants performed well on the true/false cover task, in which they judged whether an Irish sentence correctly described a given picture. The mean accuracy score was 87.69% (SD = 16.62%) on active-passive trials and 92.34% (SD = 7.08%) on dative trials. Within the active-passive set, accuracy was lowest on passive trials (86.5%), while on active trials it was comparable to performance on the dative set (92.94%). This difference could reflect an increased processing load for passive sentences, associated with their low frequency in Irish. Nevertheless, the generally high accuracy rate suggests that participants understood the prime sentences in most cases. In the following analyses we included all trials with scorable responses, regardless of accuracy on the true/false task, since excluding incorrect trials did not change the pattern of results.

Transitive event descriptions were scored as active if they featured the agent in subject position, followed by the verb, and the patient in object position (e.g., *The dancer pushed the waitress*). Descriptions were scored as passive if they featured the patient as the subject of the sentence, the verb, and the agent in a prepositional *by* phrase (e.g., *The teacher was weighed by the nun*). Non-transitive descriptions were scored as ‘other’, as were descriptions that only referred to one entity in the picture. This included patient-focusing constructions that omitted the agent (i.e., short passives), in accordance with the scoring criteria typically applied in adult priming studies (e.g., Hartsuiker et al., 2004). We also carried out analyses based on a more lenient scoring scheme, often used in the developmental priming literature (e.g. Branigan and McLean (2016). Under lenient scoring, short passives that omitted the *by*-phrase (e.g., *The boxer got hit*) were counted along with full passives.

Participants produced 1909 descriptions, of which 1516 were active (79.41%), 46 were full passives (2.41%), 114 were short passives (5.97%), and 233 were

scored as ‘other’ responses under the lenient scheme (18.17%). Table 3 displays the frequency and proportion of passive, active, and ‘other’ responses following each prime type, based on strict and lenient scoring schemes separately. The rate of passive production was very low across all conditions, although marginally higher after a passive prime than after an active or baseline prime.

	<b>Baseline</b>		<b>Active</b>		<b>Passive</b>	
<i>Strict scoring</i>	Freq.	Prop.	Freq.	Prop.	Freq.	Prop.
Passive response	14	0.02	12	0.02	20	0.03
Active response	509	0.80	519	0.81	488	0.77
Other response	116	0.18	108	0.17	123	0.19
<i>Lenient scoring</i>						
Passive response	51	0.07	47	0.06	62	0.08
Active response	509	0.80	519	0.81	488	0.77
Other response	79	0.13	73	0.13	81	0.15

**Table 3.** Frequency (Freq.) and proportion (Prop.) of passive, active, and ‘other’ responses by prime condition, based on strict and lenient scoring schemes.

Due to the very small number of full passives produced in Experiment 1, there were insufficient data points to conduct a reliable analysis of syntactic priming based on the strict scoring scheme. We carried out an exploratory analysis of priming under the lenient scoring scheme by fitting a mixed logit model to the re-coded response data; however, we did not find a main effect of passive priming nor an interaction between priming and proficiency. It is conceivable that this result reflects the small number of observations per condition, even with the inclusion of short passives, resulting in insufficient power.

Dative event descriptions were scored as double object (DO) if they contained the agent, the verb, and the recipient immediately followed by the theme (e.g., *The cook lends the boxer a cake*). Descriptions were scored as prepositional object (PO) when the theme was named first, followed by the recipient in a prepositional *to* phrase (e.g., *The painter handed a jug to the dancer*). Non-dative descriptions, and those that did not name all three entities, were scored as ‘other’.

Participants produced 1718 descriptions, of which 751 were scored as double-object datives (43.71%), 345 as prepositional-object datives (20.08%), and 622 as ‘other’ responses (36.2%). Table 4 shows the frequency and proportion of PO, DO, and ‘other’ responses following baseline and dative primes.

	Baseline		Dative	
	Frequency	Proportion	Frequency	Proportion
PO response	155	0.18	190	0.22
DO response	378	0.44	373	0.43
Other response	323	0.38	299	0.35

**Table 4.** Frequency and proportion of prepositional-object (PO), double-object (DO), and ‘other’ responses by prime condition.

The relatively high proportion of ‘other’ responses in the dative set is partly due to the frequency of incomplete responses, missing at least one argument (23.28%). It is possible that some participants did not manage to write down a complete dative sentence containing three entities within the time allowed. We also observed legitimate descriptions of dative events involving passive constructions (160 instances, e.g., *The painter was awarded a banana*). This may reflect a tendency of specific target verbs to attract the passive, or the transfer of a passive priming effect to subsequent dative trials. However, evidence for the rapid decay of priming in written production (Branigan, Pickering, & Cleland, 1999) makes this unlikely to be a “leaked” effect of previous exposure to passive sentences, as exploratory analysis revealed that passive descriptions of dative events were not any more prevalent when the preceding trial was passive than when it was active.

#### Mixed logit model of dative responses

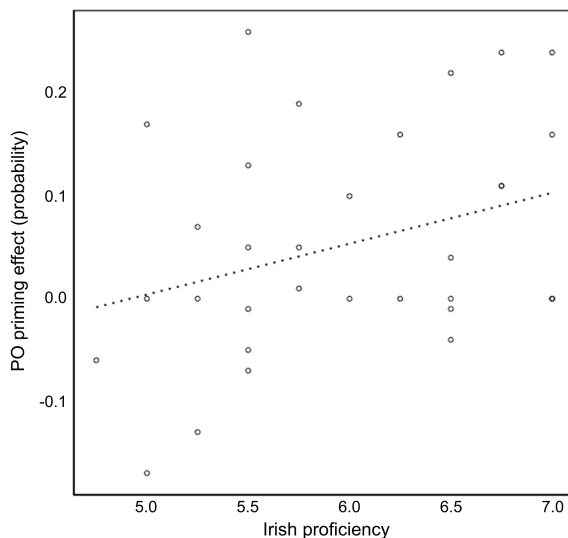
We fit a generalised logistic mixed model to predict the occurrence of PO responses in the dative dataset, using the *lme4* package in R, version 1.0.153 (Bates et al., 2014). PO responses were as coded as ‘1’ and DO and all other responses were coded as ‘0’. The model included random intercepts for items, target verbs, and participants, as well as by-target verb and by-participant random effects of Prime Type. Prime Type (Baseline/Dative) was a fixed factor in the model. We included self-rated Irish Proficiency as a continuous predictor, to

investigate the relationship between L2 proficiency and cross-linguistic syntactic priming. Irish Proficiency was averaged across speaking, listening, reading, and writing, and entered into the model as a mean-centred score. 11 participants were excluded from the modelling analysis due to missing language history data.

The model results are summarized in Table 5. The negative intercept reflects a baseline preference for the DO dative. There is a small positive effect of Prime Type on the log-odds likelihood of a PO response, based on the 95% confidence interval for the coefficient having a lower bound very near to zero. While self-rated Irish proficiency does not predict the use of PO datives in English, the model results indicate a positive interaction between Irish proficiency and Prime Type. That is, participants with higher self-rated proficiency were more likely to produce an English PO dative after reading an Irish dative prime than after a non-dative baseline prime. This result suggests that the observed 4% difference in PO production between conditions (shown in Table 4) was largely driven by the higher-proficiency participants. Figure 5 illustrates the positive relationship between self-rated Irish proficiency and individual differences in the magnitude of the PO priming effect.

Predictor	Coefficient	SE	z value	95% CI
Intercept	-2.12	0.46	-4.61	-3.02, -1.22
Prime Type: Dative	0.36	0.20	1.78	-0.04, 0.76
Irish Proficiency	-0.62	0.38	-1.60	-1.37, 0.14
Prime Type: Dative x Irish Proficiency	0.53	0.23	2.32	0.08, 0.98

**Table 5.** Summary of fixed effects in the mixed logit model (N = 1293, log-likelihood = -555.9). The intercept represents the log-odds of a PO response in the non-dative baseline condition (NP NP NP) for a participant with average Irish proficiency. SE = Standard Error; CI = Confidence Interval.



**Figure 5.** Irish-to-English PO priming effect as a function of self-rated Irish proficiency (7-point scale, averaged across speaking, listening, reading, and writing). The priming effect is the probability of producing a PO dative in the dative priming condition, minus the baseline probability. Participants who produced a higher proportion of POs at baseline than after a dative prime thus show a negative effect.

In sum, our results indicated a small effect of dative priming, which was modulated by self-rated proficiency in Irish, the priming language. Despite its considerably different surface structure, the Irish dative may be more connected to the English PO than to the DO dative in abstract representational space, as a result of congruent constituent order (Direct object + Indirect Object). Interpreting our results within the developmental model of L2 syntactic acquisition (Hartsuiker & Bernolet, 2017), this structural overlap had a more facilitating effect for higher-proficiency participants because they are equipped with more abstract representations of Irish (L2) structures, presumably allowing for a greater degree of connectedness with existing representations of English (L1) structures.

We did not find the same pattern of results in the active-passive set. Overall, the rate of passive production was very low. Even under a more lenient scoring

system that included short passives, there was only a marginal difference in the proportion of passive responses following a passive prime relative to baseline. In addition, exploratory analysis did not show evidence for an interaction with Irish proficiency, as we observed for dative priming. However, we interpret this result with caution given the number of data points, which was arguably insufficient to assess interaction effects reliably.

It is not clear whether the weak evidence for cross-linguistic syntactic priming in Experiment 1 reflects the linguistic distance between Irish and English or methodological factors, such as the use of written sentence generation in a classroom setting. To address this question, we conducted a within-language control experiment (Experiment 2). We used the same design and procedure as Experiment 1, with English-only materials and an age-matched group of students attending English-medium schools. If we find much stronger evidence for priming within language than between languages, we might conclude that the representations of equivalent structures in English and Irish are connected but not fully integrated, perhaps due to insufficient overlap in surface structure, which might restrict cross-linguistic priming. If, on the other hand, we do not observe the expected main effect of within-language syntactic priming in Experiment 2, the most likely conclusion will relate to methodological factors.

## **Experiment 2**

Experiment 2 investigated within-language syntactic priming (English to English), using written sentence generation in a classroom setting.

### **Method**

#### *Participants*

54 native English speakers (32 female), aged 14-17 ( $M=16.02$ ,  $SD=0.76$ ) were recruited from two English-medium secondary schools in the mid-west and south east of Ireland. Informed written consent was obtained from students and their

parents prior to participation. As Irish is taught as a compulsory subject in most schools at primary and secondary level, all participants had had some degree of exposure to the language. However, based on responses to the Irish Language History Questionnaire (summarised in Table 6), participants' self-rated proficiency ( $M=4.27$ ,  $SD=1.53$ ) was on average lower and more variable than that of the Irish-educated group in Experiment 1. We compared the mean proficiency ratings for the two groups using a Welch's T-test ( $t = 2.89$ ). The standardised effect size (1.36) indicates that the magnitude of the difference is large. Furthermore, in contrast to the Irish-educated group's daily use of Irish, two thirds of the English-educated group reported rarely using Irish in conversation, while the remaining third did so only in weekly Irish lessons at school. Therefore, we conclude that participants in Experiment 2 differ substantially from participants in Experiment 1 in terms of their self-rated Irish language proficiency, experience, and frequency of use. Standardised exam results for English suggest that academic performance was also more variable in this group, with grades ranging from A to E at higher level. Amongst the 49 participants who responded, the distribution of grades was A: 6%, B: 27%, C: 39%; D: 27%; E: 2%.

Variable	Mean (SD)	Range
Age at testing	16.02 (0.76)	14 – 17
Age when began acquiring Irish (years)	4.88 (1.29)	3 – 10
Speaking proficiency (7pt)	4.24 (1.62)	1 – 7
Listening proficiency (7pt)	3.94 (1.65)	1 – 7
Reading proficiency (7pt)	4.60 (1.29)	1 – 7
Writing proficiency (7pt)	4.30 (1.49)	3 – 7

**Table 6.** Profile and self-rated Irish language proficiency of participants in Experiment 2 (n=50).



### *Design & Materials*

The design and materials were identical to those described in Experiment 1, except that the prime sentences had been translated into English.

### *Procedure*

Participants were tested in their school classrooms, in two groups of 30 and 24 students, respectively. The set-up and procedure were the same as for Experiment 1, except that the cover task required participants to respond ‘true’ or ‘false’ to English descriptions of the prime pictures. As in Experiment 1, participants generated written descriptions to target pictures in English.

## **Results and discussion**

Overall, accuracy on the true/false cover task was high, indicating that participants read and understood the prime sentences. The mean accuracy score was 96.21% (SD=4.18%) on active-passive trials and 96.10% (SD=7.75%) on dative trials. As in Experiment 1, the analyses included all trials with scorable responses, regardless of accuracy on the true/false task.

We used the same coding schemes described in Experiment 1 to score participants’ written descriptions of transitive and ditransitive events. Participants produced 2457 transitive event descriptions, of which 1952 were active (79.45%), 104 were full passives (4.23%), 155 were short passives (6.31%), and 246 were scored as ‘other’ responses under the lenient scoring scheme (10.00%). Under the strict scoring scheme, ‘other’ responses included short passives, as well as non-transitive and incomplete sentences. The frequency and proportion of passive, active, and ‘other’ responses following each prime type are displayed for both strict and lenient scoring schemes in Table 7. Across conditions, we observed very few full passives; however, there was a numerical trend towards producing more passives after passive primes than after active or baseline primes. As both scoring schemes yielded the same pattern of results, below we report analysis based on the strict scoring scheme.

	Baseline		Active		Passive	
	Freq.	Prop.	Freq.	Prop.	Freq.	Prop.
<i>Strict scoring</i>						
Passive response	27	0.03	29	0.04	48	0.06
Active response	655	0.80	663	0.81	634	0.77
Other response	135	0.17	124	0.14	142	0.17
<i>Lenient scoring</i>						
Passive response	73	0.09	81	0.10	107	0.13
Active response	655	0.80	663	0.81	634	0.77
Other response	89	0.11	72	0.09	83	0.10

**Table 7.** Frequency (Freq.) and proportion (Prop.) of passive, active, and ‘other’ responses by prime condition, based on strict and lenient scoring schemes.

#### Mixed logit model of passive responses

We used the ‘lme4’ package in R to fit a generalised logistic mixed model to the active-passive dataset. Full passive responses (e.g., *The boxer was hit by the cowboy*) were as coded as ‘1’, and active and all ‘other’ responses were coded as ‘0’. The model included random intercepts for items, target verbs and participants, and a by-participant random effect of Prime Type. We added a random effect of Prime Type by School to account for the possible variance introduced by testing participants in two different schools. The fixed factor in the model was Prime Type (Baseline/Active/Passive), with Baseline taken as the reference level. We recoded participants’ English exam grades (A-E) as a numeric score (5-1). This new variable, English Score, was mean-centred and entered into the model as a continuous covariate, including an interaction with Prime Type.

The model results summarised in Table 8 show that the log-odds of producing a full passive in the baseline condition was well below zero, reflecting the observed strong preference for actives. Since the 95% confidence interval for the Prime type: Passive coefficient encompasses zero, we cannot conclude that there was a within-language passive priming effect. Thus, these results match those of Experiment 1. In addition, the model results show no evidence for a main effect

of English Score on the likelihood of a passive response, nor an interaction between English score and either Prime Type.

Predictor	Coefficient	SE	z value	95% CI
Intercept	-3.99	0.40	-9.87	-4.79, -3.20
Prime Type: Passive	0.15	0.59	0.25	-1.01, 1.30
Prime Type: Active	-0.22	0.58	-0.39	-1.36, 0.91
English Score	0.50	0.45	1.10	-0.39, 1.39
Prime Type: Passive x English Score	0.05	0.59	0.10	-1.11, 1.22
Prime Type: Active x English Score	0.01	0.58	0.01	-1.12, 1.13

**Table 8.** Summary of fixed effects in the mixed logit model (N = 2248, log-likelihood = -349.9). The intercept represents the log-odds of a passive response in the baseline condition (NP + NP) for a participant with an average English score. SE = Standard Error; CI = Confidence Interval.

Participants produced 2351 ditransitive event descriptions, of which 719 were scored as double-object datives (30.58%), 798 as prepositional-object datives (33.94%), and 833 as ‘other’ responses (35.43%). Table 9 displays the frequency and proportion of PO, DO, and ‘other’ responses following baseline and dative primes. The proportions indicate an 8% increase in the production of PO datives in the PO prime condition relative to the non-dative baseline.

	Baseline		Dative	
	Frequency	Proportion	Frequency	Proportion
PO response	355	0.30	443	0.38
DO response	386	0.33	333	0.28
Other response	431	0.37	403	0.34

**Table 9.** Frequency and proportion of prepositional-object (PO), double-object (DO), and ‘other’ responses by prime condition.

### Mixed logit model of dative responses

We used the procedure described in Experiment 1 to fit a mixed logit model to the within-language dative priming dataset. From the previous model we retained Prime Type as a predictor and added School to the random effects structure. The final model therefore comprised Prime Type (Baseline/Dative) as a fixed factor, random intercepts for item, target verb, and participant, as well as by-participant and by-school random effects of Prime Type. Again, we added mean-centred English Score as a covariate, including its interaction with Prime Type.

Consistent with the observed 8% increase in the rate of PO production in the PO priming condition relative to baseline, Table 10 shows a positive coefficient for the predictor Prime Type: PO Dative. As zero falls outside the 95% confidence interval for this coefficient, we can conclude that there is evidence for a within-language PO priming effect. The model results reveal no main effect of English Score on PO production. Furthermore, there was no evidence for an interaction between English Score and Prime Type, suggesting that the within-L1 PO priming effect was independent of L1 proficiency.

Predictor	Coefficient	SE	z value	95% CI
Intercept	-1.74	0.83	-2.10	-3.37, -0.11
Prime Type: PO Dative	0.58	0.16	3.53	0.26, 0.90
English Score	-0.27	0.46	-0.57	-1.18, 0.64
Prime Type: PO Dative x English Score	0.30	0.19	1.58	-0.07, 0.69

**Table 10.** Summary of fixed effects in the mixed logit model (N = 2152, log-likelihood = -955.9). The intercept represents the log-odds of a PO dative response in the baseline condition (NP + NP + NP) for a participant with an average English score. SE = Standard Error; CI = Confidence Interval.

### Exploratory combined analysis of Experiments 1 and 2

To determine whether within-language syntactic priming was stronger than between-language priming for PO datives, we conducted an exploratory combined analysis of the binary response data from Experiment 1 and Experiment 2. We created a mixed logit model to predict the log-likelihood of producing a PO dative as a function of the fixed factors Prime Type (Baseline/Dative), Prime Language (Irish/English), and, importantly, their

interaction. The reference level for the Prime Language variable was Irish (i.e., the cross-linguistic priming condition, since the target language was always English). The model included separate random effects of Prime Type by school ( $n=3$ ), and by participant ( $n=105$ ), as well as random intercepts for target verb and item.

Predictor	Coefficient	SE	z value	95% CI
Intercept	-2.28	0.77	-2.94	-3.80, -0.76
Prime Type: Dative	0.32	0.15	2.06	0.02, 0.62
Prime Language: English	0.80	0.87	0.92	-0.90, 2.50
Prime Type: Dative x Prime Language: English	0.25	0.18	1.34	-0.11, 0.61

**Table 11.** Summary of fixed effects in the mixed logit model for Experiments 1 and 2 combined ( $N = 4068$ , log-likelihood = -1785.8). The intercept represents the log-odds of a PO response in the baseline condition (NP + NP) when the language of priming is Irish. SE = Standard Error; CI = Confidence Interval.

The negative intercept shown in Table 11 reflects a baseline preference for the DO dative in the Irish priming condition (i.e., Experiment 1). When we combine the datasets from both experiments, the model results indicate a main effect of Prime Type on the log-likelihood of a PO response, based on a 95% confidence interval. This is consistent with the numerical trend observed in both experiments, whereby more English PO datives were produced following an Irish dative or English PO prime, relative to the non-dative baseline. The interaction of interest, between Prime Type and Prime Language, has a positive coefficient but a 95% confidence interval that encompasses zero. Thus, we did not find evidence that the priming effect was stronger in Experiment 2 than in Experiment 1.

## General discussion

The present study investigated between- and within-language syntactic priming of passives and datives, using written sentence generation in a classroom setting.

In Experiment 1, bilingual Irish speakers read Irish primes and generated sentences in English to describe target pictures. Prime and target sentences were always semantically unrelated, with non-equivalent main verbs. In Experiment 2, an age-matched control group read English translations of the prime sentences from Experiment 1 and completed the same picture description task.

Based on previous studies supporting a less-restricted account of shared syntax in bilinguals (e.g., Shin & Christianson, 2009; Kutasi et al., 2018), we predicted that the Irish dative would prime production of the English PO dative in Experiment 1. The Irish dative shares some elements of constituent order with the English prepositional-object dative, although the two constructions differ with respect to surface constituent structure (NP NP vs. NP PP) and position of the main verb. Consistent with our hypothesis, Experiment 1 showed a small increase in the proportion of English PO datives produced after an Irish dative prime, relative to a non-dative baseline. This appeared to be driven by participants who rated their Irish proficiency the highest (averaged across modalities). Importantly, higher proficiency was not associated with a baseline preference for PO datives in English; on the contrary, more proficient participants showed a bias towards the DO (double object) dative at baseline.

The interaction between cross-linguistic priming and proficiency in Experiment 1 is similar to a finding reported by Bernolet, Hartsuiker, and Pickering (2013). They examined self-rated L2 proficiency as a predictor of syntactic priming magnitude in Dutch-English bilinguals and found a robust positive correlation. Indeed, less proficient participants did not show any between-language priming for genitives in their study. Contrastingly, Kutasi and colleagues (2018) reported a main effect of Scottish Gaelic proficiency on passive production in English, but no interaction between proficiency and priming. However, as they noted in their discussion, a more heterogeneous sample might be required to investigate the effect of proficiency systematically.

Based on the results obtained with late bilinguals, Bernolet and colleagues (2013) posited that the interaction between L2 proficiency and cross-linguistic priming arises from the progressive abstraction of structures across languages. That is, L2 learners begin with language-specific, item-based representations for new syntactic structures, which gradually become integrated with existing representations of similar structures in L1. This account assumes that highly proficient bilinguals activate the same representations when encoding similar syntactic structures in their two languages, giving rise to a cross-linguistic syntactic priming effect. For less proficient bilinguals, between-language influences may be weaker or absent, because syntactic encoding involves

separate representations for L1 and L2. The evidence we found for proficiency-modulated priming between Irish and English datives is compatible with this theoretical account and supports the claim that even non-identical structures undergo a process of integration, given sufficient proficiency in both languages.

We contrast the results of Experiment 1 with those of Experiment 2, which suggested that within-language dative priming was unrelated to native language proficiency as indexed by English exam scores, though non-equivalent proficiency measures may limit the potential for direct comparison between experiments. Within a native language, the interaction between syntactic priming effects and linguistic proficiency might be a function of developmental stage. For example, Kidd (2012) found that grammatical knowledge and vocabulary predicted syntactic priming in 4-to-6-year-old native English speakers. By the time they reach adolescence, it is likely that native speakers have reached a plateau in syntactic acquisition, at least for the most common structures of their language, where abstract representations of those structures (e.g., the PO dative) are fully developed, facilitating syntactic priming between sentences with no lexical overlap. Our finding in Experiment 2, that within-L1 priming for PO datives was robust and independent of L1 proficiency, could thus reflect the efficiency of syntactic encoding for this structure, perhaps too close to ceiling to show an effect of proficiency. By this reasoning, priming for passives might be expected to show a comparatively larger effect of linguistic proficiency in adolescents, as the structure is less common and therefore should plateau later. While we did not find evidence in our data to support this, future work could address the issue using a syntactic priming paradigm that elicits more passives.

The developmental account of L2 syntactic acquisition (Hartsuiker & Bernolet, 2017) has implications for the relative strength of between- versus within-language priming effects, since it predicts that only highly proficient bilinguals with fully integrated structural representations should prime as strongly between languages as within. Several studies have found evidence for equivalent effects, independent of the priming language (e.g., Schoonbaert et al., 2007; Kantola & Van Gompel, 2011). More recently, Hartsuiker and colleagues (2016) systematically investigated the issue in multilingual speakers and found that syntactic priming was always as strong between as within languages, supporting a fully shared syntax account (e.g., Hartsuiker et al., 2004). However, this finding did not hold for the less proficient bilinguals tested by Bernolet and colleagues (2013), leading them to conclude that the shared syntax model in fact represents the final state of bilingual memory, whereas the prevalence of language-specific representations in less proficient bilinguals results in weaker

priming from L2 to L1 than within L2. Converging with Hartsuiker et al. (2016), we did not find evidence for a significant difference between Irish-to-English and within-English dative priming in terms of magnitude. This exploratory finding points to the engagement of shared, or tightly linked syntactic coding operations for Irish and English, at least in the more proficient bilinguals.

In contrast to the results obtained for the dative construction, we did not find any passive priming. Kutasi and colleagues (2018) studied adolescent bilingual speakers of Scottish Gaelic and English and demonstrated cross-linguistic passive priming with one of the two Gaelic patient-focusing structures they tested. The present study tested a similar sample in terms of age and L2 proficiency, using materials adapted from the Scottish Gaelic study. As Scottish Gaelic shares many typological features with Irish, including VSO word order, we had expected to find a comparable effect of passive priming in Irish-speaking bilinguals in Experiment 1. However, in our study, the overall rate of full passives (2.41%) was even lower than in the study by Kutasi and colleagues (5.71%) and did not allow us to detect any existing priming effects. Further work is needed to provide a more conclusive test of Irish-to-English passive priming.

Although the overall rate of passive production in both of our experiments was very low, participants in Experiment 2 produced relatively more passive descriptions than participants in Experiment 1 (4.23%). We speculate that this may reflect group differences in experience with written English, and by extension with the English passive, which is used more frequently in formal written text than in colloquial spoken language (Roland, Dick, & Elman, 2007). Whilst adolescents educated through Irish undoubtedly gain exposure to written English outside of school, the distribution of passives in their input is unlikely to be equivalent to that of their English-educated peers, who consume a large volume of English educational texts, typically of a formal register. Notably, English exam results did not predict passive production in Experiment 2, indicating that the observed group difference in passive avoidance is unlikely to be related to general aptitude, but rather to experience. This explanation is compatible with the evidence that exposure to print, and specifically to the structural distributions of written language, influences syntactic choices in production (Montag & MacDonald, 2015).

Despite the slightly higher rate of passive production overall in Experiment 2, we did not find evidence for a within-language passive priming effect. This is contrary to previous studies that have demonstrated syntactic priming of the passive in English, both in adults (e.g., Bock, Dell, Chang, & Onishi, 2007) and in children (e.g., Messenger, Branigan, McLean, & Sorace, 2012). Our finding



that the same participants exhibited priming for the PO dative in Experiment 2 indicates that they were not resistant to syntactic priming *per se*. However, it may be that passive priming effects, which tend to be smaller in magnitude than dative priming effects (Mahowald et al., 2016), are more sensitive to variations in experimental design.

Although passive primes did not yield the expected priming effect in either study, we did obtain varying degrees of evidence for dative priming both within and between languages using a classroom-based, written sentence generation paradigm. This finding might encourage other researchers to adopt similar approaches, in order to assess theories of language processing in samples with different educational and language backgrounds to those typically tested in psycholinguistic studies. Classroom-based testing may require some adaptations of standard protocols, such as written rather than spoken response elicitation, and very carefully formulated instructions, while the increased likelihood of distraction remains difficult to avoid. Nevertheless, the present study may be taken to demonstrate the feasibility and potential of using classroom settings in syntactic priming research. Compared to web-based testing, which also allows for the efficient acquisition of large datasets, group testing offers the benefit of closer observation and tighter control of participants' behaviour during the experiment.

### *Conclusion*

This study investigated cross-linguistic syntactic priming in bilingual adolescents receiving their education through Irish, which is typologically distant from English (the culturally dominant language in Ireland). We found that self-reported Irish proficiency predicted the strength of dative priming from Irish to English, in-line with previous evidence from Dutch-English bilinguals. A control experiment conducted at English-medium secondary schools showed a comparable within-L1 priming effect for PO datives. This was not modulated by L1 proficiency, possibly because the processing of relatively common structures in L1 was close to ceiling. Our findings are compatible with a developmental account of L2 syntactic acquisition, which assumes that the shared representations necessary for between-language priming emerge with increasing proficiency.

### Appendix A. Sample page from answer booklet.

	true	false
1. Bhí an gadaí leanta ag an bpóilín.	<input type="checkbox"/>	<input type="checkbox"/>
2. Describe in English.	<div></div>	
3. Thug an foghláí mara cáca don dornálaí.	<input type="checkbox"/>	<input type="checkbox"/>
4. Describe in English.	<div></div>	

## Appendix B. Irish Language History Questionnaire

### 1) Age when you...

Began Acquiring Irish:	Began Reading in Irish:	Began Writing in Irish:

### 2) How often do you use Irish in conversation? *(Please circle as appropriate)*

Daily                      Weekly                      Monthly                      Rarely

### 3) Is Irish used in your home?    Yes                                      No

If yes, by whom?    *(Please circle all that apply)*

Parents/ Primary Caregiver    Grandparents    Siblings    Child-minder

Other (Please Specify): .....

### 4) How often do you engage with Irish Media (e.g., TV, Radio, or Newspapers)?

Daily                      Weekly                                      Monthly                                      Rarely

### 5) Please rate the level of your Irish proficiency for each section:

1 = Very Low and 7 = Very Comfortable

	Very Low					Very Comfortable	
Reading:	1	2	3	4	5	6	7
Speaking:	1	2	3	4	5	6	7
Writing:	1	2	3	4	5	6	7
Understanding							
Spoken Language:	1	2	3	4	5	6	7

### 6) Excluding Irish and English, can you hold a conversation in any other languages? Yes / No

If yes, please specify which language(s):

.....

### 7) Which grade did you receive for Irish in the Junior Cert? Grade:    Level:

Which grade did you receive for English in the Junior Cert? Grade:    Level:

# 7. Summary and discussion

Among the myriad characteristics that differentiate ‘book language’ from typical conversational speech, syntactic complexity and diversity are among the most salient. As a consequence, avid readers and avoidant readers have qualitatively different patterns of syntactic experience that presumably grow more divergent with age. How do these experiential differences manifest in adult language users’ explicit knowledge and implicit processing of syntactic structures? Especially in the spoken domain, the effects of literacy on syntactic processing are not well understood. This thesis aimed to further our understanding, from the standpoint that within a nominally literate society like the Netherlands, differential engagement in literacy activities should yield continuous effects on cognitive processes and knowledge structures (Stanovich, 1993; Stanovich & West, 1989). In a series of studies with non-reading impaired adults, I examined literacy experience as a source of variation in syntactic knowledge and processing. This chapter summarises the main findings and considers their contribution to the existing literature. Limitations and directions for future research are also discussed.

Chapter 2 reported on a pre-registered study in which I evaluated the contribution of long-term written language experience to offline and online syntactic processes in a community-based sample of 161 adult native Dutch speakers. The index of written language experience was a principal component score combining six literacy-related measures: receptive vocabulary, word and pseudoword reading, spelling, author recognition, and reading habits.

To assess offline syntactic knowledge, I used an auditory grammaticality judgment task. The task targeted prescriptive grammatical norms that are reliably attested in written language, but frequently violated in informal spoken Dutch: *als/dan*, *hun/ze*, *mij/ik*, *die/dat* (Hubers et al., 2016). I predicted that participants with less literacy experience would have more difficulty recognising prescriptive norm violations (i.e., their judgments would be more likely to reflect the syntactic

patterns of spoken language). Controlling for the contribution of non-verbal IQ, verbal working memory, and processing speed, I observed a robust effect of literacy experience on the detection of grammatical norm violations in spoken sentences. This result converges with and extends previous findings from Street and Dąbrowska (2010), suggesting that exposure to ‘book language’ has specific benefits for general (modality-independent) syntactic knowledge.

Chapter 2 contributes to the existing literature on the status of prescriptive grammatical norms in contemporary Dutch (Hubers & de Hoop, 2013; Hubers et al., 2019; van Bergen et al., 2011). Previous studies have used reading tasks to evaluate grammaticality (e.g., Hubers et al., 2020; Hubers et al., 2016), despite the fact that norm violations occur almost exclusively in spoken language. In this respect, my approach using auditory presentation provided a more ecologically valid measure of grammaticality than other investigations to date. Note, however, that the task is not a ‘pure’ measure of syntactic knowledge, given that other factors contribute to performance including, to a large degree, individual attitudes to prescriptive norms. While evidence suggests that some Dutch native speakers perceive norm violations more negatively than others do (Hubers et al., 2016), I did not control for such differences in my study, possibly confounding the results. Future work on grammaticality and grammaticality judgments should also probe participants’ overt attitudes to the prescriptive norms under investigation. Alternatively, some previous studies have avoided eliciting normative judgments altogether (e.g., “Is this a correct sentence?”), instead asking participants to what degree sentences “sound natural” (e.g., Feathersen, 2004). This approach is proposed to tap more directly into intuitions about well-formedness and might be less coloured by perceptions of grammatical prestige.

The second strand of Chapter 2 concerned online syntactic processing, indexed by comprehension-to-production priming of the Dutch dative alternation. The dative alternation (i.e., *She gave a key to the doctor* vs. *She gave the doctor a key*) is ubiquitous in the syntactic priming literature, and has yielded robust effects in many languages, including Dutch (Bernolet et al., 2010; Hartsuiker et al., 2008; for a meta-analysis see Mahowald et al., 2016). I took this well-established psycholinguistic phenomenon as a starting point for exploring the relationship between written language experience and syntactic processing in

spoken language. Although there is suggestive evidence that language users vary in their susceptibility to priming, the vast majority of syntactic priming research has focused on effects at the group level, treating between-participant variability as noise. As a result, we know little about the factors that drive individual differences in syntactic priming (cf. Kidd, 2012). I speculated that for adult language users, a possible candidate could be differences in long-term syntactic experience (indexed by written language experience). For example, following activation-based models of information processing, infrequent structures receive a larger boost than frequent structures from the same amount of activation (residual activation being one proposed mechanism for syntactic priming; Pickering & Branigan, 1998). Individual patterns of syntactic experience lead to different input frequencies, which could feasibly manifest in the degree of syntactic priming for certain structures. Although I did not have a priori expectations regarding the Dutch dative alternation (due to insufficient corpus data), I tentatively hypothesised an inverse relationship between written language experience and the magnitude of syntactic priming.

My results replicated previous findings of robust comprehension-to-production dative priming at the group level, both with and without lexical overlap between prime and target. At the individual level, I observed considerable variation in syntactic priming behaviour, with many participants showing no priming at all, or even a negative effect (comparable to the variability previously demonstrated in children; Kidd, 2012). Although literacy experience was associated with differential usage of PO/DO datives at baseline, it did not modulate their priming; a null effect I considered robust, given the large sample size. I concluded that long-term experience with written language may affect implicit syntactic choices in spoken language (as per MacDonald & Montag, 2015), but has no detectable effect on syntactic priming of the dative alternation in adult native speakers. I could not rule out the possibility that a different target structure might have yielded a different result. Indeed, with hindsight, one could question the suitability of the dative alternation for probing experience-related differences in priming, given the common occurrence of both PO and DO constructions in everyday spoken Dutch. In this respect, it could be informative for future studies to target syntactic priming of a structure with a clear

asymmetrical distribution across spoken and written language (such as the passive), although eliciting infrequent or non-preferred structures in spoken production potentially presents a methodological challenge.

While these data suggest that individual variability in syntactic priming behaviour may be the norm rather than the exception, they do not bring us closer to understanding the sources of such variability. It is worth noting that priming effects showed only moderate within-participant consistency in my experiment, which may have limited the potential for meaningful interactions with participant-level covariates. Task reliability is recognised as a limiting factor for individual differences research in psycholinguistics (Kidd et al., 2018). All in all, alternative approaches are likely to be more fruitful for exploring literacy-related differences in online syntactic processing (as described in Chapter 4, for example).

Chapter 3 built on the findings reported in Chapter 2 with respect to literacy experience and grammaticality judgment. I constructed a broad-based assessment of receptive syntactic knowledge, motivated by the theoretical dichotomy of ‘core’ versus ‘peripheral’ grammar (Broekhuis, 2016; Broekhuis & Keizer, 2012; Chomsky, 1993). One aim of Chapter 3 was to establish the empirical basis for these categories in Dutch by assessing adult native speakers’ knowledge of syntactic structures that had been classified as either ‘core’ or ‘peripheral’ by a majority of linguist informants during an extensive pre-testing phase. I also aimed to investigate the extent to which individual differences in knowledge (as indexed by grammaticality judgments) were related to literacy experience. To this end, participants were sampled from the extremes of the literacy experience distribution, based on their principal component score in Chapter 2.

I observed systematic differences in grammaticality judgments that broadly corresponded to linguists’ intuitions regarding ‘core’ and ‘peripheral’ syntactic structures. Notably, however, there was substantial variability in participants’ judgments within these categories, which speaks for a continuum of prevalence rather than a categorical distinction between ‘core’ and ‘peripheral’ grammar (acceptance rates for ‘core’ structures ranged from 57 – 100%).

Contrary to my prediction, individual differences in literacy experience explained only a small amount of the variance in grammaticality judgments of

both ‘core’ and ‘peripheral’ structures. On the basis of task modality, a stronger association with literacy experience might have been expected in Chapter 3 (written) relative to Chapter 2 (auditory). On the other hand, the short stimulus presentation time without an option to listen again arguably increased the cognitive demands of the auditory task relative to the written task (in which it was possible to re-read each sentence for up to 20 seconds). The discrepancy in findings is, however, most easily explained by distributional properties of the target structures. Literacy experience matters for knowledge of prescriptive grammatical norms, which are most reliably attested in books, but less so for ‘core’ syntactic structures which, by definition, are encountered in informal speech. Meanwhile, ‘peripheral’ structures may have such restricted usage (e.g., legal register), that typical reading activities do not offer adequate exposure.

The focus on receptive syntactic knowledge in Chapter 3 complements recent work by Hulstijn (2017), describing syntactic commonalities in the spontaneous *production* of a heterogeneous group of adult native Dutch speakers. Encouragingly, I observed some overlap between the shared productive knowledge reported by Hulstijn (2017), and the structures that were most widely recognised in my grammaticality judgment task. However, my conclusions about ‘core’ grammar were constrained both by the non-exhaustive list of structures tested, and the relatively small sample size. Ideally, large-scale prevalence studies are needed to gain a comprehensive picture of syntactic knowledge at a population level (perhaps equivalent to the Dutch Lexicon Project; Brysbaert et al., 2016).

Chapters 4 and 5 involved the same two groups of participants described above (i.e., a subset of the original sample from Chapter 2). These groups represented opposite ends of the literacy experience distribution: low literacy experience (LLE) and high literacy experience (HLE). In Chapters 4 and 5, literacy experience group was examined as a categorical predictor of anticipatory syntactic processing in spoken language. I used the visual world paradigm as a tool to access the parsing process in real time, measuring eye-movements to a predictable target in the visual scene *before* it was mentioned in the speech signal. In Chapter 4, prediction of an upcoming agent required listeners to exploit syntactic constraints in the unfolding passive sentence that indicated passive



voice (and thus afforded a sentence-final agent). I hypothesised that highly experienced literates would move their eyes to the plausible agent in the scene faster than less experienced literates, reflecting more efficient syntactic analysis.

Controlling for the speed of language-mediated looking on non-predictive trials (and for general cognitive abilities), I observed a robust main effect of literacy experience on anticipatory syntactic processing in Chapter 4. I speculated that this was driven by modality-independent syntactic representations and predictive processes, which are thought to be enhanced by reading (see Huettig & Pickering, 2019, for further discussion). The processing advantage for highly experienced literates also fits with the proposal that frequency of exposure to syntactic constraints (e.g., through reading) facilitates their activation during online sentence comprehension (Pearlmutter & MacDonald, 1995). Although this investigation was the first to my knowledge to focus specifically on syntactic prediction in relation to literacy, it converges with the existing body of evidence for literacy-related differences in spoken language prediction based on other types of linguistic information (Huettig & Brouwer, 2015; Mani & Huettig, 2014; Mishra et al., 2012; Ng et al., 2018).

In Chapter 5, I examined the predictive effect of a different syntactic cue (verb transitivity), originally demonstrated in English by Arai and Keller (2013, Experiment 1). I was interested in whether this finding could be extended to Dutch, which shares with English the syntactic constraint that transitive verbs require a direct object. My visual world eye-tracking experiment was similar in design to Arai and Keller, except that only two spoken sentence conditions were contrasted: transitive and intransitive. Based on Arai and Keller's findings, I expected listeners to anticipate a direct object in the transitive condition (indexed by eye-movements to the only compatible entity in the visual scene), as opposed to the intransitive condition, where no direct object was licensed. While there was a numerical trend in the expected direction, the effect of verb transitivity on anticipatory eye movements was not statistically robust. I was therefore unable to draw conclusions about the contribution of literacy experience to verb-mediated syntactic prediction.

Several possible reasons were discussed for the failure to replicate Arai and Keller's syntactic prediction effect in Chapter 5. Among them, the lack of a

neutral control condition was likely a significant limiting factor. This could be corrected in a follow-up study using intransitive verbs that do not license a prepositional object. However, given the small size of the original effect, I speculated that verb transitivity may not be a crucial source of information for syntactic prediction in normal spoken language comprehension.

The studies reported in Chapters 3, 4, and 5 involved the same two groups of participants and thus share the same limitation concerning sample size. The groups were selectively recruited from the original community-based sample ( $N = 161$ ) to be maximally different in terms of literacy experience. To this end, I only invited participants from the top and bottom quartiles (i.e., approximately half of the original sample). Due to a relatively low response rate, combined with a large number of invitees having moved away in the intervening period, the final sample size was approximately 50% of the target. Clearly, data from 80 participants would have allowed me to draw stronger conclusions regarding the contribution of literacy experience to individual differences in syntactic proficiency.

Finally, Chapter 6 reported on fieldwork carried out in secondary schools in Ireland. Here, I examined the effect of long-term language experience on syntactic processing from a different perspective, via two syntactic priming experiments: (1) Between-language priming with bilinguals educated through Irish Gaelic, and (2) Within-language priming with age-matched controls educated through English (2). In Experiment 1, I observed Irish-to-English priming for PO datives, despite considerable differences in surface constituent structure between primes and targets (Irish uses VSO word order and case marking). The strength of priming correlated with bilingual participants' self-rated Irish (L2) proficiency, in line with some previous studies (e.g., Bernolet et al., 2013). This finding is compatible with the idea that the shared syntactic representations involved in between-language priming develop gradually during L2 acquisition. In contrast, within-language PO priming in Experiment 2 was independent of English (L1) proficiency (indexed by standardised exam results), likely reflecting a plateau in L1 syntactic acquisition, at least for common structures like the dative. From a methodological perspective, this study demonstrated the feasibility of using a written sentence generation paradigm in a

classroom setting to collect a large amount of priming data efficiently. Furthermore, by investigating a well-established syntactic processing phenomenon in a previously untested population and a minority language, the study contributed to increasing diversity within psycholinguistic research.

### *Future directions*

The work in this thesis signposts some potentially useful avenues for future research into the benefits of literacy beyond reading. Syntactic prediction in spoken language, for instance, warrants further attention as a window onto individual differences in syntactic processing. Establishing literacy experience as a source of this variation would speak for the benefits of reading for processing spoken language, in so far as prediction (pre-activating upcoming information) supports comprehension. As a first step, it would be important to replicate the findings reported in Chapter 4 with a larger sample and to establish the consistency of the prediction effect within participants (an important precondition for individual difference research; Kidd et al., 2018). Predictive processing of different sentence structures with different syntactic affordances (e.g., a relative pronoun licensing a relative clause) could then be investigated using a similar visual world design to elicit anticipatory eye-movements. For the purposes of illuminating literacy-related differences in syntactic prediction, a community-based sample is likely to show the most individual variation on both predictor and outcome variables. In addition, a composite of measures is recommended to provide a reliable index of literacy experience with sufficient sensitivity across the distribution.

Only receptive components of syntactic knowledge were probed in this thesis (Chapters 2 and 3). However, differential effects of written language experience may be easier to detect in production tasks (picture description, for example). Compared to recognising a syntactic structure (e.g., in a grammaticality judgment task), producing it in a sentence clearly requires a higher level of mastery, and might therefore be more sensitive to any enhancing effect of literacy experience. This would likely depend on the distributional properties of the structure in question (i.e., its relative frequency in ‘book language’ versus spoken language), as Montag and MacDonald (2015) demonstrated for relative clause usage in

English. Using a principled approach similar to theirs (corpus analyses followed up with elicited sentence production experiments), further research could investigate the extent to which the syntactic choices of highly experienced literates tend to echo the structural distributions of written Dutch. Comparative corpus analyses of contemporary Dutch texts and conversational speech would provide valuable data both for this endeavour and for related lines of research.

Finally, evidence from cross-sectional studies such as those reported in this thesis can only bring us so far towards understanding how syntactic knowledge and processing might be altered and extended by literacy experience itself. Without tightly controlling for other environmental correlates of written language exposure such as SES, educational attainment, occupation, and family reading practices, the exact locus of experiential differences remains ambiguous. Longitudinal studies are needed to elucidate the specific, causal role of literacy experience in native speakers' mastery of syntax. For example, a study that monitored the syntactic skills of (functionally) illiterate adults before, during, and after literacy training could have particularly strong explanatory power. Such a training study was originally intended to form part of this thesis, involving members of the Irish Traveller community enrolled on a literacy programme. Unfortunately, cuts to the adult education budget in Ireland resulted in the cancellation of state-funded literacy programmes for the Traveller community several months before the study was planned to start.

### *Conclusion*

This thesis set out to explore the role of literacy experience in explaining individual differences in syntactic knowledge and processing. I applied behavioural and eye-tracking methods to address the issue from a variety of perspectives, focusing on the non-reading impaired adult population. Offline measures of receptive syntactic knowledge provided variable evidence for a contribution of literacy experience, likely modulated by the distributional properties of target structures. The starting point for exploring online syntactic processing was comprehension-to-production syntactic priming, which showed no evidence of literacy-related differences. However, examining syntactic processing through the lens of prediction proved more fruitful, revealing a

positive association between literacy experience and listeners' predictive parsing of passive sentences. Although an open question remains as to how widespread literacy-related differences in syntactic prediction are, this preliminary finding makes a novel contribution to our understanding of the relationship between literacy and spoken language processing in the relatively under-researched syntactic domain. In sum, my thesis provides evidence from a literate population, demonstrating the different ways and degrees to which syntactic abilities are shaped by differential engagement in literacy activities.

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## Nederlandse samenvatting

De meeste boeken zijn niet geschreven zoals we spreken. Schrijvers hebben de neiging ideeën uit te drukken in langere, uitgebreidere zinnen, vaak met behulp van syntactische (grammaticale) constructies die zelden voorkomen in alledaagse gesproken taal. Dat maakt ‘boekentaal’ een rijke bron van syntactische diversiteit voor lezers (en luisteraars die worden voorgelezen of naar luisterboeken luisteren). Op volwassen leeftijd verschilt de totale leeservaring van een enthousiaste lezer aanzienlijk van die van een onwillige lezer, die in het dagelijks leven misschien nauwelijks wordt blootgesteld aan ‘boekentaal’. Tussen deze uitersten zit natuurlijk een breed spectrum aan leesgedrag en daarom verwachten we aanzienlijke individuele verschillen in geletterdheidservaring, zelfs binnen nominaal geletterde populaties zoals de Nederlandse bevolking. Als taalkennis door ervaring wordt gevormd, zoals door veel eerder onderzoek wordt gesuggereerd, hebben mensen die zich meer bezighouden met lees- en schrijfactiviteiten dan ook betere syntactische vaardigheden? Wat betekenen individuele verschillen in geletterdheidservaring voor a) de kennis van grammaticale structuren van volwassen moedertaalsprekers, en b) hoe die structuren worden verwerkt in hun begrip van gesproken taal? Tot op heden heeft onderzoek naar de voordelen van geletterdheid weinig aandacht besteed aan syntactische vaardigheden. Mijn proefschrift had als doel om dit gat in onze kennis te vergroten aan de hand van een verscheidenheid aan experimentele benaderingen. Hier vat ik de belangrijkste bevindingen samen.

Hoofdstuk 2 onderzocht de relatie tussen enerzijds geletterdheidservaring en anderzijds aspecten van syntactische kennis en verwerking in een steekproef van 161 volwassen Nederlandse moedertaalsprekers. Waarom 161? Eerder onderzoek met computersimulaties toonde aan dat dit het minimale aantal deelnemers is dat nodig is om de correlatie tussen twee variabelen betrouwbaar te kunnen schatten. Psycholinguïstische studies gebruiken doorgaans een steekproef van bachelorstudenten. Om het scala aan vaardigheden en ervaringen binnen de hele bevolking beter weer te geven, heb ik zoveel mogelijk deelnemers buiten de ‘universiteitsbubbel’ geworven (bijv. bij het lokale mbo-college). Omdat geletterdheidservaring een complexe kwaliteit is waarvoor geen perfect

meetinstrument bestaat, heb ik een reeks verschillende geletterdheidstests afgenomen (woordenschatkennis, voorlezen van echte woorden en nonwoorden, spelling, naamherkenning van auteurs, leesgewoonten en leeshouding). Deze zes metingen werden statistisch gewogen in een enkele score, die ik gebruikte als een index van geletterdheidservaring, niet alleen in hoofdstuk 2, maar ook in studies in de daaropvolgende hoofdstukken.

Het eerste deel van hoofdstuk 2 onderzocht individuele verschillen in syntactische kennis met betrekking tot grammaticale regels. Deelnemers luisterden naar gesproken zinnen, waarvan sommige de grammaticale regels van het standaard Nederlands overtraden (bijv. “Steven heeft eerder dan mij [ik] zijn rijbewijs gehaald”). Ze moesten voor iedere zin beoordelen of deze grammaticaal correct was. De resultaten lieten zien dat gevoel voor grammaticale overtredingen sterk gecorreleerd was met geletterdheidservaring: degenen die het hoogst scoorden op de index van geletterdheidservaring waren ook het meest geneigd om zinnen te beoordelen volgens de prescriptieve grammaticale regels van het standaard Nederlands. Belangrijk hierbij is dat het effect van geletterdheidservaring onafhankelijk was van de algemene cognitieve vaardigheden van deelnemers (non-verbaal IQ, verbaal werkgeheugen en verwerkingssnelheid). Deze bevinding komt overeen met eerder gevonden bewijs voor een verband tussen blootstelling aan ‘boekentaal’ en syntactische kennis.

In hoofdstuk 3 bleek echter dat de mate van het verband gevonden in hoofdstuk 2 afhankelijk is van de syntactische structuren die worden onderzocht. In hoofdstuk 3 werden dezelfde deelnemers gevraagd een groter aantal syntactische structuren te beoordelen. De helft van deze structuren was door een groep Nederlandse taalkundigen beoordeeld als ‘standaard’ (bekend bij de meeste moedertaalsprekers) en de andere helft als ‘ongewoon’ (onbekend bij veel moedertaalsprekers). Over het algemeen kwamen de grammaticaliteitsoordelen van de deelnemers overeen met de intuïties van de taalkundigen; ‘standaard’ structuren werden vaker geaccepteerd als grammaticaal dan ‘ongewone’ structuren. In tegenstelling tot de resultaten van hoofdstuk 2, was geletterdheidservaring hier echter niet sterk geassocieerd met grammaticaliteitsbeoordelingen op individueel niveau; het kwart van de

deelnemers met de meeste geletterdheidservaring scoorde namelijk niet significant beter dan het kwart met de minste ervaring.

Het tweede deel van Hoofdstuk 2 betrof de realtime verwerking van syntactische structuren. Uit onderzoek blijkt dat mensen de neiging hebben om onlangs waargenomen syntactische te hergebruiken, zonder dat ze zich daar bewust van zijn - een fenomeen dat bekend staat als *syntactic priming*. Zo zal iemand die net de zin “De danser geeft een appel aan de dokter” heeft gehoord, in een beschrijving van een afbeelding eerder “De leraar schenkt een hoed aan de piraat” zeggen dan “De leraar schenkt de piraat een hoed”. Deze twee zinnen betekenen hetzelfde, maar verschillen in hun syntactische structuur. Mijn hypothese was dat er een verband is tussen de impliciete verwerking van syntactische structuren in gesproken taal (gekwantificeerd door middel van *syntactic priming*) en de syntactische ervaring van een individu op de lange termijn (gekwantificeerd door middel van geletterdheidservaring). In overeenstemming met eerder onderzoek, vond ik bewijs voor een effect van *syntactic priming* in de Nederlandse datiefconstructie (het meewerkend voorwerp in “Zij geeft een appel aan de dokter/Zij geeft de dokter een appel”). De grootte van het effect varieerde echter aanzienlijk van persoon tot persoon. In tegenstelling tot mijn hypothese was deze variatie niet afhankelijk van verschillen in geletterdheidservaring - een nulresultaat dat, gezien de grootte van de steekproef, waarschijnlijk stand houdt.

Bij elkaar genomen bestaan er vermoedelijk effectievere methoden dan *syntactic priming* voor het onderzoeken van verschillen in syntactische verwerking in het begrip van gesproken taal op basis van geletterdheid. Syntactische voorspelling is een veelbelovend alternatief dat ik heb onderzocht in hoofdstuk 4 en 5 met behulp van eyetracking, een methode waarbij de oogbewegingen van proefpersonen worden gemeten. De term *syntactische voorspelling* verwijst naar het vermogen van luisteraars om op basis van de syntactische zinstructuur te anticiperen op opkomende informatie in de zin. In de zin “De watermeloen wordt inderdaad geschopt door een ezel”, kun je bijvoorbeeld al vroeg voorspellen dat er een levende entiteit betrokken is bij wat de watermeloen ondergaat. Dat komt deels door de grammaticale aanwijzingen in de zin die duiden op de passieve vorm (bijv. het hulpwerkwoord “wordt”). In



Hoofdstuk 4 mat ik de oogbewegingen van deelnemers met veel en weinig geletterdheidservaring terwijl ze luisterden naar passieve zinnen en tegelijkertijd naar een scherm met vier plaatjes keken (in dit geval een watermeloen, een ezel en twee ongerelateerde levenloze objecten). De resultaten toonden aan dat de deelnemers met meer geletterdheidservaring sneller dan deelnemers met minder ervaring geneigd waren hun ogen te richten op de meest plausibele agens (de handelende entiteit, in het voorbeeld “de ezel”) in de zin *voordat* deze werd genoemd. Dit suggereert dat ze de syntactische informatie in de zich ontvouwende zin efficiënter geanalyseerden. Belangrijk hierbij is dat statistische analyse van de resultaten aantoonde dat dit verschil niet alleen te danken was aan snellere woordherkenning of een beter werkgeheugen. Zodoende kunnen we concluderen dat geletterdheidservaring de voorspellende verwerking van gesproken passieve zinnen verbetert. Als zodanig vormt dit resultaat een aanvulling op reeds bestaand onderzoek dat op basis van andere taalkundige verschijnselen (zoals grammaticaal geslacht) een samenhang heeft gevonden tussen geletterdheid en voorspellende taalverwerking.

Samengevat heeft het onderzoek in dit proefschrift individuele verschillen in syntactische kennis en de verwerking daarvan onder de aandacht gebracht, als ook de rol van geletterdheidservaring hierop onderzocht in een gezonde volwassen populatie. Bij elkaar genomen suggereren mijn bevindingen dat een grotere betrokkenheid bij geletterdheidsactiviteiten voordelen kan hebben voor syntactische vaardigheden, afhankelijk van hoe ze worden gemeten. Het voorlopige bewijs voor aan geletterdheid gerelateerde verschillen in syntactische voorspelling tijdens de verwerking van gesproken zinnen vormt een veelbelovende richting voor toekomstig onderzoek.

## English summary

Most books are not written the way we speak. Writers tend to express ideas in longer, more elaborate sentences, often using syntactic (grammatical) constructions that are rarely encountered in everyday spoken language. These qualities make ‘book language’ a rich source of syntactic experience for readers (also for bedtime story- and audiobook-listeners). By adulthood, the cumulative experience of an avid reader differs considerably from that of a reluctant reader, who might hardly be exposed to ‘book language’ in their daily life. Between these extremes there is of course a wide spectrum of reading behaviour, which is why we expect to find substantial individual differences in literacy experience, even within nominally literate populations like the Netherlands. If linguistic knowledge is shaped by experience, as much previous research suggests, do people who engage more in literacy-related activities have enhanced syntactic abilities? Specifically, what do individual differences in literacy experience mean for a) adult native speakers’ knowledge of syntactic structures, and b) how those structures are processed in *spoken* language? To date, research into the benefits of literacy has not given much attention to syntactic abilities. My thesis aimed to address this relative gap in our understanding, using a variety of experimental approaches. Here I summarise the main findings.

Chapter 2 investigated the relationship between literacy experience on the one hand and aspects of syntactic knowledge and processing on the other, in a sample of 161 adult native Dutch speakers. Why 161? Previous research using computer simulations showed that this is the minimum number of participants needed to reliably estimate the correlation between two variables. Psycholinguistic studies typically sample undergraduate students. However, to better represent the range of ability and experience that exists in the general population, I made an effort to recruit as many participants as possible from outside the ‘university bubble’. Since literacy experience is a complex attribute for which no perfect measurement tool exists, I administered a battery of literacy-related tests (vocabulary knowledge, reading aloud real and non-words, spelling, author name recognition, and reading habits). These measures were statistically combined to

give a single score, which I used as an index of literacy experience, not only in Chapter 2 but also for the studies described in subsequent chapters.

The first part of Chapter 2 examined individual differences in syntactic knowledge with respect to prescriptive grammatical rules. Participants listened to spoken sentences, some containing violations of grammatical rules in Dutch (e.g., “Steven heeft eerder dan mij zijn rijbewijs gehaald”, *Steven got his driving license earlier than me*), and had to judge whether or not each sentence was grammatically correct. I found that sensitivity to grammatical violations was robustly correlated with literacy experience, such that those who scored highest on the literacy experience index were most likely to judge sentences according to the prescriptive grammatical rules of their language. Importantly, the effect of literacy experience was independent of general cognitive abilities (non-verbal IQ, verbal working memory, and processing speed). This finding is in line with previous evidence for a link between exposure to ‘book language’ and syntactic knowledge.

The results of Chapter 3, on the other hand, suggested that the strength of this relationship may vary, depending on the structures under investigation. In Chapter 3, participants who ranked in the top 25 percent for literacy experience in Chapter 2, as well as those who ranked in the bottom 25 percent, were invited to take a test that targeted a large set of syntactic structures. Here, the task was to judge written sentences that featured grammatically ‘legal’ structures in Dutch. Half of the structures had previously been rated by a group of Dutch linguists as ‘core’ (known by most native speakers), and half as ‘peripheral’ (unknown to many native speakers). Overall, participants’ judgments were consistent with linguists’ intuitions; ‘core’ structures were more likely than ‘peripheral’ structures to be accepted as grammatical. However, in contrast to the results reported in Chapter 2, literacy experience was not strongly associated with grammaticality judgments at the individual level

The second part of Chapter 2 concerned the real-time processing of syntactic structure. A large body of research shows that people tend to re-use structures they have recently processed without being consciously aware of doing so – a phenomenon known as syntactic priming. For example, a speaker who has just heard *The dancer gave an apple to the doctor* is more likely to say *The teacher*

*offered a hat to the pirate* than *The teacher offered the pirate a hat* when asked to describe a picture of that event. The last two sentences have the same meaning; the only difference is their syntactic structure. I hypothesised that the implicit processing of syntactic structures in spoken language (indexed by syntactic priming), might be related to an individual's long-term syntactic experience (indexed by literacy experience). Like several previous studies, I found that the Dutch dative construction (e.g., “Zij geeft een sleutel aan de leraar”, *She gives a key to the teacher*) showed an overall syntactic priming effect. However, the strength of syntactic priming varied considerably from person to person. Contrary to my hypothesis, this variation appeared unrelated to individual differences in literacy experience – a null finding that is likely to be robust, given the large sample size.

All in all, alternative approaches to syntactic priming are likely to be more fruitful for exploring literacy-related differences in syntactic processing in spoken language. One approach that shows promise is syntactic prediction, which I investigated using eye-tracking methods in Chapters 4 and 5. I use the term syntactic prediction to refer to listeners' ability to anticipate upcoming information based on syntactic clues in the unfolding sentence. For example, early on in the sentence “De watermelon wordt inderdaad geschopt door een ezel”, *The watermelon is indeed kicked by a donkey*, you may be able to predict that there will be an animate agent involved in whatever is happening to the watermelon. That is partly because of clues in the sentence that signal passive voice (e.g., the passive auxiliary “wordt” in Dutch). In Chapter 4, I tracked the eye movements of participants with high and low literacy experience as they listened to passive sentences like the one above, while looking at a visual scene with four pictures (in this case a watermelon, a donkey, and two unrelated objects). The data revealed that the more experienced literates were more likely than the less experienced literates to move their eyes to the most plausible agent in the visual scene (e.g., the donkey) *before* it was mentioned. This suggests that they analysed the syntactic information in the unfolding sentence more efficiently. Importantly, statistical modelling showed that the advantage was not simply due to faster word recognition or better working memory, allowing me to conclude that literacy experience itself enhances the predictive processing of

spoken passive sentences. This result extends the existing evidence base for literacy-related differences in spoken language prediction based on other types of linguistic cues (e.g., grammatical gender).

To sum up, the research described in this thesis shone a spotlight on individual differences in native speakers' syntactic knowledge and processing and explored the role that literacy experience might play in determining these differences in the healthy adult population. Taken together, my findings suggest that increased engagement in literacy activities may have some benefits for syntactic abilities, depending how they are measured. In particular, preliminary evidence for literacy-related differences in syntactic prediction during spoken sentence processing points to this as a promising avenue for future research.

## **Biographical note**

Saoradh Favier was born in Newcastle upon Tyne, United Kingdom, in 1991. After completing her bachelor's degree in French and Russian at the University of Cambridge in 2013, she decided she wanted to be a speech and language therapist. It was while studying for her master's degree in Speech and Language Therapy at the University of Limerick, Ireland, that she dipped a toe into psycholinguistics and liked it. Deciding to dive in, she moved to the Netherlands in 2016 to take up a position at the Max Planck Institute for Psycholinguistics, Nijmegen. Four years and one PhD later, she's glad she did. Saoradh now lives in Amsterdam with her partner Arne and Moon the cat.



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